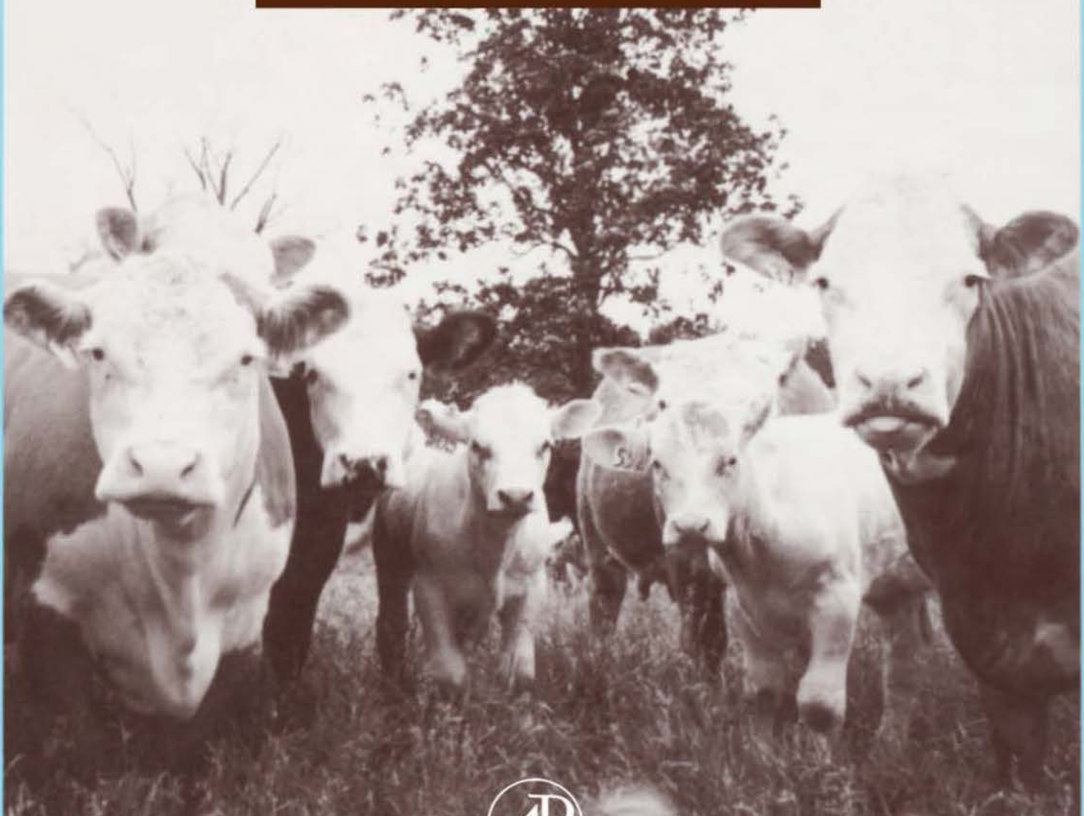
Beef Cattle Feeding and Nutrition

Second Edition



Edited by

Tilden Wayne Perry and Michael J. Cecava

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Dedicated by the senior editor to

Dr. James Tilden Perry

And to quote from the Good Book,

"My son, in thee I am well pleased!"

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Preface to the Second Edition

Livestock and poultry consumption per capita, as boneless equivalent weight, has surpassed 170 lb (77 kg) since 1988 (*Feedstuffs*, November 7, 1994, summary of USDA figures) in the United States. It is interesting to note that while the figure in 1960 was 140 lb, it had risen to 160 lb by 1967; the figure rose to 170 lb in 1976, then dropped off a bit, but subsequently surpassed 170 lb by 1988. Of this total, beef consumption started off at 60 lb (27 kg) in 1960, rose to a peak of over 80 lb from 1974 to 1978, and settled down through the 70- and high 60-lb levels to 60 lb (27 kg) by 1993. Current predictions suggest that total livestock and poultry boneless equivalent weight will surpass 180 lb (80 kg) during the 1990s. It is proposed that the consumption of beef will remain constant—or perhaps rise.

In order to compete with other types of meat, beef cattle producers must meet the challenge of producing wholesome meat. It seems that consumers purchase a growing but finite amount of animal protein each year. If the consumption of one type of meat increases significantly, the consumption of another type of meat probably will decline. Beef cattle nutrition, genetics, and physiology practices have improved greatly in the past decade or two, enabling beef producers to compete with other types of meat for the consumer's purchases. It is to the advantage of the cattle producers to use newer techniques of producing and marketing beef.

This second edition of *Beef Cattle Feeding and Nutrition* embraces and includes the very latest in production techniques, which will enable cattle producers to continue to produce highly desirable beef as economically as possible.

Tilden Wayne Perry

Preface to the First Edition

Beef cattle production is indeed an exciting discipline wherever it can be followed in this world. In the United States, the sale of cattle for beef is the number one source of income to agriculture by a wide margin.

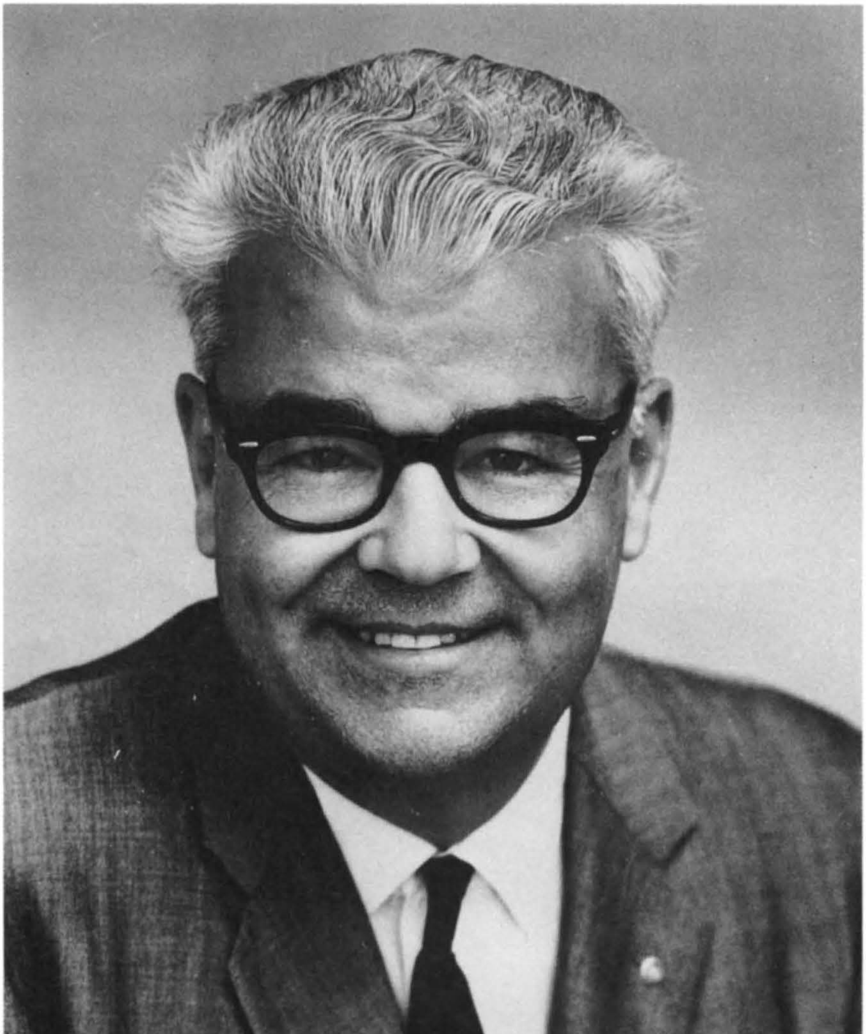
Type and style of beef cattle may change for a time, and thus several extreme types have appeared. Therefore, the author has no sections whatsoever on breeds or types because such sections get out of date too quickly, and thus they would appear to "date" such a text too rapidly.

Nutrition and management are based on the best interpretations of scientific facts and the application of such facts. Therefore, even though changes are occurring in the nutrition and management of beef cattle, in general they tend to be more gradual. Because this text contains the latest scientific findings, such information remains intact until newer and more refined knowledge has been obtained.

The area of beef cattle nutrition has advanced a long way, but most beef cattle nutritionists realize that so much remains unknown, compared to what we know about this discipline, that it behooves us to pursue the subject diligently. A good case in point has been the first real breakthrough in the nutrition of the rumen in the mid-1970s; the volatile fatty acid production of the rumen could be changed dramatically through the oral administration of a minute amount of monensin.

Beef Cattle Feeding and Nutrition is meant to be a compilation and interpretation of the latest on the subject. It is meant to represent (1) a literature review, (2) a text, and (3) a useful handbook.

Tilden Wayne Perry



In Memoriam

Tony J. Cunha

1916–1992

Tony J. Cunha served as Editor of the series Animal Feeding and Nutrition for almost 20 years. Because of his many years in this capacity, it seems fitting that a brief tribute to his lifetime of service to the animal industry be included here.

Tony Cunha was born on a dairy farm near Los Banos, California, on August 22, 1916, and died after a short illness, in November 1992.

He attended California Polytechnic State University in San Luis Obispo, California, from 1936 to 1939, and received his B.S. and M.S. degrees from Utah State University, Logan, in 1940 and 1941, respectively. In 1944 he was awarded a Ph.D. degree in Biochemistry and Nutrition from the University of Wisconsin—Madison, where he was influenced very much by the pioneer research of Gustav Bohstedt. He also had the opportunity to work with Drs. E. B. Hart, Conrad Elvejhem, H. Steenbock, Karl Paul Link, and Paul Phillips.

While at Utah State University, Tony met his future wife, Gwen Smith of Logan, Utah. Tony and Gwen were married in 1941, and they celebrated their 50th wedding anniversary on September 1, 1991. Their three daughters are Becky Jane Mallory, Anchorage, Alaska; Sharon Marie Buddington, Lilburn, Georgia; and Susan Ann Choinski, Conway, Arkansas.

Tony's professional career began in 1944 with four years at Washington State University, Pullman, researching animal nutrition with swine and sheep, and teaching production and animal nutrition courses. From there he moved on to the University of Florida, to serve for 27 years, organizing the university's first Animal Science Department and serving as its chairman for 25 years. In 1975, he became Dean of Agriculture at California Polytechnic State University, Pomona. He retired as Dean Emeritus on September 1, 1980; however, he continued to serve as University Consultant for the next 10 years.

When Tony arrived at the University of Florida, he was an Associate Professor of Animal Science, serving with five other members of the department; when he departed 27 years later, the Animal Science Department had grown to 49 faculty members at the Gainesville campus and seven branch experiment stations.

Dr. Cunha's area of research was in animal nutrition. His early research dealt

with basic concepts of swine, including B vitamin and mineral requirements, and the use of antibiotics in swine nutrition. He authored many scientific and professional articles. In 1968 the American Society of Animal Science awarded him its most prestigious honor, the F. B. Morrison Award for Outstanding Contribution to Scientific Research in the Field of Animal Science.

Dr. Cunha was a member of more than a dozen scientific and honor societies, and is listed in eleven "Who's Who" type books. He provided leadership to a number of organizations that serve the animal industry, including serving as Vice President and President of The American Society of Animal Science, and as Chairman of the Animal Nutrition Committee of the National Academy of Science, National Research Council.

Tony was an outstanding teacher, administrator, and researcher. In 1951 he initiated the Florida Annual Beef Cattle Short Course, and in 1967 began the International Livestock Short Course (in Spanish), both of which have continued uninterrupted since then. In 1981, Tony and Gwen endowed an annual scholarship for a student majoring in animal science.

In 1976, Dr. Cunha took on the challenge as serving as Editor of this series on Animal Feeding and Nutrition with Academic Press; in 1977, the first book was published, *Swine Feeding and Nutrition*. Working with seven other authors, by 1992 a total of 13 books had been published. Tony's last book was the second edition of *Horse Feeding and Nutrition,* published in 1990.

Those who knew Tony have surely missed his leadership, his intellect, his knowledge of livestock problems and opportunities, his sense of humor, and the sound of his unique laughter.

Lee R. McDowell

I

Nutrient Requirements of Beef Cattle

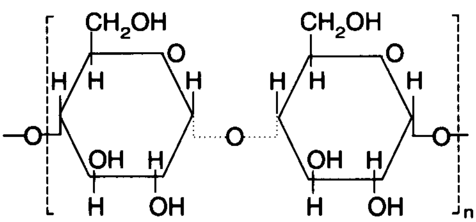
1

Rumen Physiology and Energy Requirements

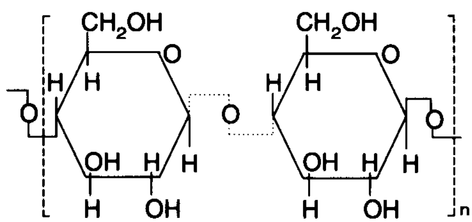
Michael J. Cecava

Ruminants are found in nearly every environment where plants transform solar energy into chemical forms. The most abundant form of renewable energy in this world is cellulose, which is synthesized by plants in the process of photosynthesis. Unfortunately man is not able to utilize cellulose as a foodstuff; ruminant animals, however, do have this ability. It is the purpose of this chapter to identify this unique capability of ruminant animals through the functioning of their rumen. This capability is a manifestation of the evolutionary processes which provided an alimentary apparatus capable of releasing the chemical energy from the structural carbohydrates of plants. No mammalian degradative enzyme is capable of "unlocking" the β-1,4-glucosidic linkages found in plant cell walls. However, microbes inhabiting the rumen have enzymes which cleave these linkages.

Repeating Maltose Unit of Starch



Repeating Cellobiose Unit of Cellulose



The major difference between starches, which can be digested by monogastric animals, and cellulose, which cannot, is the spatial configuration about the 1,4-glucosidic bond. As shown above, glucose units are joined by β-1,4 linkages in cellulose and α-1,4 linkages in starch. This difference is one of the major factors that led to the evolutionary development of the ruminant animal. Ruminants and other herbivores developed symbiotic relationships with microbial populations having enzymes capable of degrading cellulose. Thus, ruminant species are of great value to man because they provide a means of capturing solar energy stored in the cellulosic bonds of plants. The fermentation of ingested feeds by the rumen microbes also has significant nutritional and metabolic implications for the host animal that will be discussed later.

I. STRUCTURE AND DEVELOPMENT OF THE RUMINANT STOMACH

The ruminant stomach is divided into four compartments, namely, the reticulum, rumen, omasum, and abomasum. The reticulum and rumen are joined by a fold of tissue (reticulorumen fold) such that ingesta may flow from one compartment to another. Most microbial activity takes place in the rumen, so this compartment will receive considerable attention in this discussion (Fig. 1.1).

The rumen is nonfunctional in newborn ruminants, but rumen fermentation starts within a few weeks after birth. Considerable growth of the rumen occurs during the first months of life with the main stimulus being solid food in the system. When the four compartments have attained their permanent relative sizes, the rumen constitutes approximately 80% of the total stomach volume. Very early in the life of the ruminant, a mixed population of bacteria and protozoa becomes established in the rumen. The rumen then may be regarded as a large fermentation chamber providing a suitable environment for the continuous culture of the microbial population.

The pH of the rumen ranges between 5.5 and 7.0, and the temperature stays very close to 103°F, which is near optimum for the many enzyme systems contained therein. The food supply to the microorganisms is provided in a more or less continuous manner. Contractions of the rumen wall help stir and mix intimately the microbes and the ingesta. The moist conditions are ideal for the reactions.

The function of the omasum is poorly understood. However, it does remove large quantities of water from the ingesta passing through this portion of the stomach; this may well be its sole function. The function of the abomasum is similar to that of the simple stomach of monogastrics.

The abomasum is a glandular compartment in which hydrochloric acid and enzymes partially hydrolyze protein. Digesta is retained in the abomasum for a

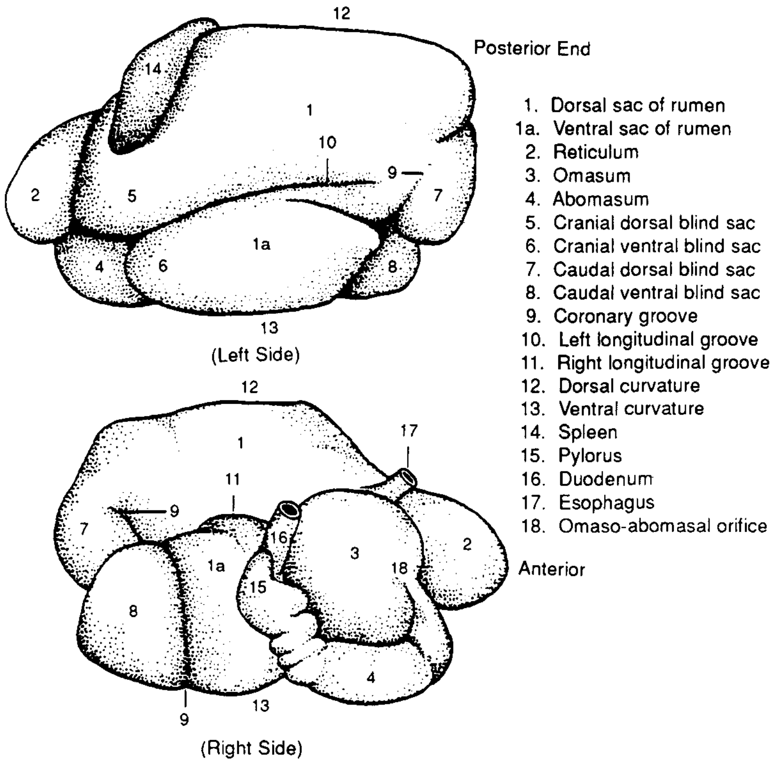


Fig. 1.1 Anatomy of the ruminant stomach. Adapted from Bone, Jesse F., "Animal Anatomy and Physiology, 3/E," © 1988, p. 160. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

relatively short amount of time (i.e., 2 to 3 h) before passing through the abomasal orifice to the upper part of the small intestine.

II. DIGESTION OF NUTRIENTS

A. Nitrogen Metabolism

Nitrogen metabolism in the rumen is a striking example of the influence of rumen microorganisms on the nutrition of the host animal. It has been recognized for more than a century that nonprotein nitrogen could be used by ruminant animals. Nitrogen metabolism in the ruminant is extremely complex. The many possible routes that ingested nitrogen may take in the ruminant animal are shown in Fig. 1.2.

The majority of protein entering the rumen is degraded to ammonia, with

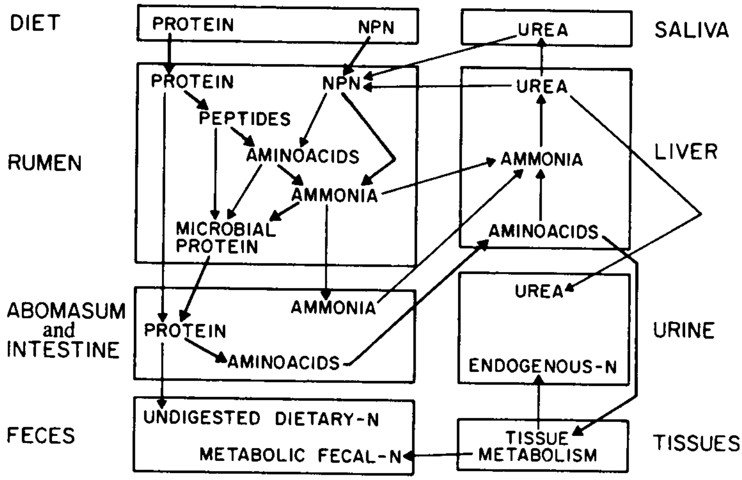


Fig. 1.2 Nitrogen metabolism in the ruminant.

protein solubility having a major effect on the extent of degradation. Protein that is relatively insoluble is degraded less, whereas more soluble protein is degraded almost totally. Casein, a highly soluble protein, is almost totally degraded. Fishmeal protein and blood albumin are much more resistant, and a large portion of these proteins escapes ruminal proteolysis. Forage and grain proteins are intermediate in their resistance to microbial breakdown. The solubility of feed proteins may be altered to the extent that they are less soluble in the rumen and thus bypass degradation. Such proteins reach the small intestine and are available for absorption. Balancing diets for optimum concentrations of ruminally degradable (RDP) and ruminally undegradable (RUP) protein is important for maximizing protein utilization. Heating of soybean protein to approximately 300°F appears to make it less subject to rumen degradation. Complexing of soybean protein with heavy metal salts, such as zinc, is another technique which apparently decreases ruminal solubility.

In addition to consuming preformed protein, ruminants obtain some dietary nonprotein nitrogen (NPN). For example, corn protein is 4% NPN, alfalfa protein is 10 to 20% NPN, and corn silage protein is 50% NPN. A portion of NPN may be indigestible, but the majority of it is converted to ammonia in the rumen. It is apparent that ammonia is a common and important intermediate in both protein and nonprotein nitrogen digestion in the rumen. A goal of ruminant protein feeding systems is to maximize the conversion of ammonia to microbial proteins and to minimize ammonia loss from the rumen by absorption.

Table 1.1 shows the usefulness of urea, a source of NPN, in beef cattle diets. One might expect urea to be more useful in diets containing high total digestible nutrients (TDN); this is not the case because efficiency of microbial protein

TABLE 1.1

Usefulness of Urea in Beef Cattle Diets[a]

Total digestible nutrients (%)	Percentage of dietary protein escaping digestion in the rumen											
	20	20	20	30	30	30	40	40	40	50	50	50
	Daily intake, % of body weight											
	1.75	2.00	2.25	1.75	2.00	2.25	1.75	2.00	2.25	1.75	2.00	2.25
	Percentage of dietary protein above which urea is useless											
75	9.46	9.88	10.23	10.58	11.04	11.43	11.99	12.51	12.96	13.83	14.44	14.95
80	8.99	9.43	9.84	10.05	10.54	11.00	11.39	11.95	12.47	13.14	13.79	14.39
85	7.98	8.33	8.66	8.92	9.31	9.68	10.11	10.55	10.97	11.67	12.17	12.66
90	6.36	6.46	6.56	7.11	7.22	7.33	8.06	8.18	8.31	9.30	9.44	9.59

[a]Adapted from NRC (1985).

synthesis declines at higher concentrate levels. Consequently, less urea nitrogen is needed by the rumen microbes. These values should be used with caution because they are based upon equations and have not been verified in extensive feeding studies. However, the following generalizations concerning urea feeding are apparent: (1) the efficiency with which urea is utilized is not constant but varies depending upon the composition of the diet prior to supplementation; (2) urea becomes more useful when feed intake is high rather than low; (3) increasing the amount of bypass protein in the diet increases the need for a ruminally available nitrogen source, such as urea.

Some ammonia is inevitably absorbed from the rumen and carried by the blood to the liver where it is converted to urea. Urea formed by the liver may take one of two possible routes: (1) it may be excreted from the body by dissolving in the urine or (2) it may be recycled into the rumen via saliva or directly through the rumen wall. The quantity of recycled urea is variable depending on the level of dietary nitrogen; 10 to 70% of dietary nitrogen may be recycled in this manner, perhaps eventually becoming synthesized microbial protein. For most feeding conditions in which diets contain adequate levels of protein, about 15% of dietary nitrogen is recycled to the rumen.

In addition to ammonia absorbed from the rumen, ammonia resulting from normal protein metabolism in the body also is detoxified by the liver. Ammonia in more than token quantities is toxic to the animal. It must, therefore, be converted to urea to render it harmless. "Urea toxicity" is a misnomer because it is actually ammonia that causes toxicity. Such a condition occurs when the concentration of ammonia in the rumen is so great that its rate of absorption into the bloodstream overwhelms the ability of the liver to convert it to urea.

Although some rumen bacteria need preformed amino acids as their nitrogen source, by far the majority of the rumen bacteria grow abundantly with ammonia as their sole nitrogen source. Ammonia is not only formed from degradation of true protein, but also from breakdown of NPN in the feed. In addition, saliva contains urea which is formed in the liver. Maintenance of ruminal ammonia concentrations in excess of the bacterial capability for utilization results in nitrogen waste.

Microbial protein is passed to the lower gastrointestinal tract where it is digested and utilized by the host animal much the same as ingested intact protein. Microbial protein composes 50% or more of the total protein entering the small intestine. The quality of protein or balance of essential amino acids of microbial protein is quite good compared with that of plant and animal proteins commonly fed to ruminants (Table 1.2). Because it is a high-quality source of protein for the animal, careful consideration should be given to balancing diets to supply adequate energy, protein, and other nutrients necessary for maximal synthesis of protein by the rumen microbes.

TABLE 1.2

Essential Amino Acid (EAA) Profiles of Ruminal Bacteria and Feed Proteins and Estimated Amino Acid Requirements for Growing Steers

	Ruminal bacteria[a]	Corn[b]	SBM[b]	Alfalfa hay[c]	Corn silage[c]	Requirements[a]
Threonine	10.13	8.22	8.64	10.18	8.99	9.14
Valine	10.05	10.17	9.73	12.49	12.83	10.96
Total sulfur (Met + Cys)	7.78	8.92	5.22	5.39	8.24	8.05
Isoleucine	9.46	6.72	8.70	9.34	8.64	10.39
Histidine	4.10	5.98	5.63	4.39	4.75	6.02
Lysine	15.29	9.28	12.85	11.00	6.87	16.52
Arginine	8.47	11.81	13.49	10.12	6.67	5.59
Phenylalanine + Tyrosine	17.47	17.77	18.55	19.51	18.96	15.09

Note. Values are % of total EAA.
[a]Adapted from Merchen and Titgemeyer (1992). Requirements are for net amino acid deposition.
[b]Ludden and Cecava (1995).
[c]Cunningham *et al.* (1993).

B. Carbohydrates

Quantitatively, carbohydrates are very important to the ruminant animal. Plant tissues contain about 75% carbohydrates. Cellulose is the most abundant organic compound in the world and composes from 20 to 50% of the dry matter of most plants. Consequently, fibrous carbohydrates, such as cellulose, are the primary source of energy for ruminants fed plant-based diets. The carbohydrates found in plant tissues are primarily polysaccharide, including hemicellulose, cellulose, pectins, fructans, and starches. Hemicellulose, cellulose and pectins are considered fibrous carbohydrates (FC), whereas fructans and starch are nonfibrous carbohydrates (NFC). The nutritive value of FC is variable and can be affected by the inherent properties of a plant material (e.g., lignification), by processing (grinding and pelleting), and by conditions occurring in the rumen (e.g., pH, particle passage rate). The nutritive value of NFC is primarily affected by the type of grain and the method of processing. These factors will be discussed in future chapters.

The main end-products of microbial carbohydrate metabolism in the rumen are short-chain organic acids, referred to as volatile fatty acids (VFA). The VFA provide 50 to 80% of the total metabolizable energy supply to the host. For grazing ruminants and those maintained on high-forge diets, little NFC passes from the rumen to be absorbed as glucose in the small intestine. Consequently, glucose is derived primarily from the gluconeogenic activity of the liver whereby

propionate and other substrates are used to synthesize glucose. Significant amounts of NFC (primarily starch) enter the small intestine in finishing cattle fed high grain diets and dairy cattle consuming large amounts of feed. However, net absorption of glucose from the gut appears to be low. Consequently, gluconeogenesis still supplies the majority of glucose needed by the animal.

1. Structural Carbohydrates

The greatest activity of the rumen, and probably the least understood, is the reduction of cellulose to its constituent units. Some authors describe this as a "three-stage" process: (a) cellulose is broken down into smaller polysaccharides which are insoluble, (b) a second stage similar to hydrolysis of other polysaccharides to glucose and cellulose, and (c) the hydrolysis of cellobiose to glucose. It is the initial stage that is not very well understood.

It appears that a number of enzymes are involved in the hydrolysis of cellulose and that the enzyme responsible for the initial attack is labile. The source of such enzymes appears to be bacterial, but some authors have suggested that protozoa and fungi may contribute to the pool of cellulases capable of breaking down cellulose.

Xylans and pentosans, which are found in hemicellulose polysaccharide, constitute a variable proportion of FC of grasses and legumes. Hemicellulose is degraded to varying extents in the rumen and the association of hemicellulose sugars with lignin can be a major factor affecting breakdown.

Other polysaccharides, such as galacturonic acid, galactans, and arabans, are found in pectin or are associated with pectin. Pectin concentration can be especially high in temperate legumes and certain by-product feeds, such as soybean hulls. Pectins generally are rapidly degraded to VFA in the rumen. Technically, pectins are considered FC, but because they are rapidly and extensively degraded in the rumen, they have properties more similar to NFC.

2. Nonfibrous Carbohydrates

Ruminal fermentation of starch is an inefficient process compared to intestinal breakdown. Fermentation of starch is only about 70% as energetically efficient as hydrolysis and absorption of glucose from starch in the small intestine.

Methane that arises from ruminal starch fermentation represents an energy loss as does the heat of fermentation which occurs in the rumen. However, starch fermentation supplies energy to the ruminal microbes and this results in the synthesis of microbial protein. Consequently, the extent of ruminal starch degradability has important implications in protein nutrition of the ruminant.

The origin of starch affects its utilization by the rumen microorganisms. For example, corn starch is much more readily degraded than potato starch. In Europe, where potato starch is utilized as a ruminant feed, it is readily obvious that some method of steaming or cooking potatoes be provided to make such feed

TABLE 1.3

Effects of Grain Type and Processing upon Starch Digestibility[a]

	Rumen (%)	Total tract (%)
Corn		
Whole, dry-rolled or steamed-whole	70	91
Steam-flaked	86	99
Sorghum		
Dry-rolled or ground	57	91
Steam-flaked, reconstituted, micronized	76	98
Barley	93	99

[a]Adapted from Theurer (1986).

more digestible. The effects of grain source and processing on starch digestibility are shown in Table 1.3. In general, about 80% of total tract starch digestion occurs in the rumen. A notable exception is barley starch, for which ruminal digestion accounts for 90% or more of total tract digestibility.

When diets rich in starch are fed to ruminants that are not accustomed to such diets, a radical change occurs in the acids present. Lactic acid content rises rapidly as does the proportion of propionic acid. Under these conditions, pH declines (acidity rises) and marked changes in the microflora occur. The above conditions exist to a lesser extent when the introduction of higher levels of starch is made more gradually; thus the practice of "bringing cattle up to a full feed gradually" can be explained. Higher starch diets consistently result in the above conditions, but cattle fed such diets gradually tend to adapt quite well.

The concentration of sugars in most diets fed to mature ruminants is low. The fermentation of glucose, fructose, and sucrose results in the production of lactic, acetic, propionic and butyric acids. Maltose, lactose, and galactose are fermented more slowly. Rate of fermentation of glucose, for example, is related to the diet. It is more slowly fermented when low-quality rather than high-quality hay is fed.

C. Volatile Fatty Acids

The total concentration of VFA in the rumen and the proportions thereof are dependent on diet. Acetic acid tends to predominate under most conditions, with propionic acid and butyric acid following, respectively (Fig. 1.3). Diets high in starch favor propionic acid production. In general, feeds which are fermented rather rapidly, as is starch, give rise to less acetic acid.

Glucose is a key intermediate in the fermentation of cell wall carbohydrates and starches to VFA. One molecule of glucose is converted by rumen microor-

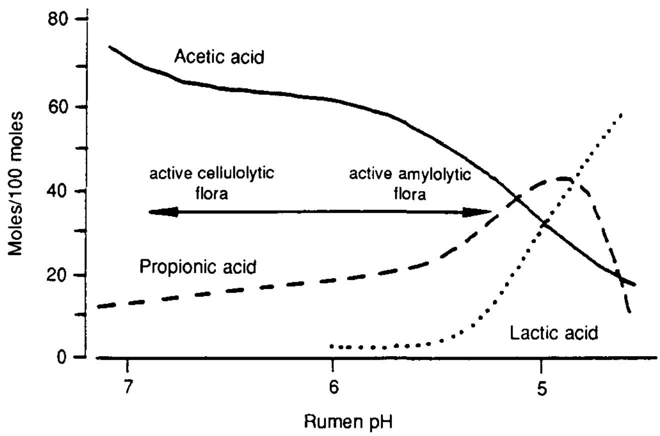


Fig. 1.3 Relationship of ruminal pH to ruminal proportions of acetic, propionic, and lactic acids. Adapted from Kaufmann *et al.* (1980).

ganisms to two molecules of 3-carbon pyruvic acid. Pyruvic acid is a second key intermediate in ruminal carbohydrate metabolism in that ultimately it can be converted to any of the VFA.

Acetic acid is produced from pyruvic acid following the loss of one carbon as CO_2.

$$1 \text{ pyruvic acid} + H_2O \Rightarrow 1 \text{ acetic acid} + CO_2 + H_2$$

Propionic acid results from addition of hydrogen to pyruvic acid.

$$1 \text{ pyruvic acid} + H_2 \Rightarrow 1 \text{ propionic acid} + H_2O$$

Butyric acid is formed by the condensation of two molecules of acetic acid.

$$2 \text{ acetic acid} + 2\ H_2 \Rightarrow 1 \text{ butyric acid} + H_2O$$

Methane is derived from the reduction of carbon dioxide by hydrogen.

$$1 \text{ carbon dioxide} + 2\ H_2 \Rightarrow 1 \text{ methane} + 2\ H_2O$$

Carbon dioxide and hydrogen are produced as a result of acetic acid formation. The production of both carbon dioxide and methane results in energy lost to the host ruminant because neither is a form of energy that can be utilized. The production of propionic acid in the rumen does not result in energy losses from gas production. Thus propionic acid production results in more efficient energy production in rumen fermentation than is true for either acetic acid or butyric acid production (Table 1.4).

It is not possible to generalize as to the relative proportions of the VFA in the rumen because diet type has a profound effect. However, cattle fed high rough-

TABLE 1.4

Efficiencies of Volatile Fatty Acid Utilization[a]

	Moles derived per mole of glucose	Gross energy (kcal/mol)	Usable energy derived/mol glucose (kcal)	Relative efficiency[b]
Acetic	2	209.4	418.8	62.2
Butyric	1	524.3	524.3	77.9
Propionic	2	367.2	734.4	109.1

[a]Adapted from Anonymous (1975).
[b]Relative to glucose (glucose = 673 kcal/mol).

age diets will have a ratio of 70% acetic, 20% propionic, and 10% butyric acid; those fed high concentrate diets tend to have a ratio of 50% acetic, 40% propionic, and 10% butyric acid.

The VFA are absorbed into the portal blood largely through the rumen wall (about 76%); some are absorbed from the omasum and abomasum (19%) and a small amount is passed on to the intestine (5%).

Acetic acid is the major end-product of the fermentation of cell wall carbohydrates by rumen microorganisms; also, the degradation of protein results primarily in acetic acid formation. The importance of acetic acid in ruminant nutrition cannot be overemphasized because it is a major energy source. In the lactating animal, acetic acid is used for milk fat production whereas in the finishing animal acetic acid is a precursor for fat synthesis. Decreasing acetic acid production can result in lower butterfat production. As an example, feeding higher levels of concentrate or finely grinding forage in diets fed to dairy cows can reduce acetic acid production and result in milk fat depression.

Most of the propionic acid that is absorbed from the gut is converted to glucose by the liver. A small amount may be metabolized to lactic acid by ruminal epithelium. Propionic acid is a precursor for about 80% of the glucose synthesized by the liver with amino acids and lactate being minor substrates for glucose synthesis.

Butyric acid is largely metabolized by the ruminal epithelia as an energy substrate. The end-products of metabolism are the ketones β-hydroxybutryate, acetoacetate, and acetone. The ketones are further oxidized by cardiac or skeletal muscle or used for fatty acid synthesis by adipose or mammary tissues.

D. Minerals

Another group of nutrients that plays an important role in the ruminant is minerals. In addition to their requirement by ruminal microbes, some of the

mineral elements have other functions. For example, physiological pH is maintained primarily by the buffering effect of the minerals; maintenance of osmotic pressure is attributed to the minerals. Mineral requirements are discussed in detail in Chapter 3.

Data from several investigators indicate that phosphorus is required by rumen microorganisms for cellulose digestion or cell growth. Iowa State researchers demonstrated an apparent preference for phosphorus sources by the rumen bacteria, particularly dicalcium phosphate followed by defluorinated rock phosphate and steamed bonemeal; preference for colloidal clay phosphorus was rather low.

Sulfur is another mineral element which is critical to normal ruminal function. The metabolism of sulfur parallels that of nitrogen. Because of the ruminal microorganisms, the ruminant animal has the ability to utilize various forms of sulfur, including inorganic sulfur. With minor exceptions, sulfide is probably the central metabolite in rumen sulfur metabolism. Sulfur is incorporated into cystine, cysteine, and methionine by the ruminal microbes. If sulfur levels are inadequate, total protein synthesis is decreased. The known conditions of ruminal sulfur metabolism, allowing for losses from the system and the direct requirements for the microorganisms, give general support to the suggestion that the dietary nitrogen to sulfur ratio should be about 10:1. This appears to be more critical when diets contain appreciable amounts of nitrogen from urea, which contributes nitrogen but not sulfur to the diet. When plant and animal protein supplements are fed, there is less likelihood of a sulfur deficiency because of the sulfur supplied by the sulfur-containing amino acids in true protein.

E. Vitamins

Most discussions on vitamin requirements tend to be of short duration, and it is concluded generally that the rumen microorganisms have no vitamin needs they cannot meet by synthesis. Ruminant diets should be supplemented with the fat-soluble vitamins, namely vitamins A, D, and E. For animals exposed to sunlight, vitamin D will be synthesized by the body. Vitamin E is particularly important because of its effects on the immune status. The water-soluble vitamins have received much less attention compared with the fat-soluble vitamins because the ruminal microbes synthesize water-soluble vitamins which then are supplied to the host. There does appear to be evidence that supplemental niacin can improve lipid metabolism by ruminants, especially lactating dairy cows. Also, there are certain conditions for which supplemental thiamin is important, for example, in cattle fed concentrate diets. Specifics of vitamin requirements will be discussed in Chapter 2.

III. QUANTITATIVE REQUIREMENTS OF BEEF CATTLE

The major nutrient requirements of beef cattle are listed in Appendix IV, Tables AIV.1 through AIV.8. Mineral and vitamin requirements, including calcium, phosphorus, and vitamin A, also are included. Requirements are expressed either as concentrations in the ration dry matter or as amounts per animal per day. All results are based on published findings and are believed to be adequate under most feeding conditions for normal health, growth, finish, and reproduction. Feed manufacturers may find it desirable, however, to increase the concentration of nutrients and ingredients that are especially susceptible to deterioration upon being mixed and/or stored. In addition, nutrient concentrations may be altered under stress conditions, e.g., increasing vitamin A and E levels in times of shipping stress.

IV. ENERGY

Energy is the first demand in all of animal nutrition. The energy need will be met first, and at the expense of all other nutrients, e.g., if the energy need is not satisfied and if protein is available, it will be broken down to satisfy the energy needs before it will be used to meet protein or amino acid needs. Furthermore, the total energy requirement quantitatively surpasses all other nutrient requirements. For example, a 650-lb finishing yearling steer has the following nutrient requirements.

	Daily	Percentage of total requirement
TDN (energy)	13.2 lb	86.2
Protein	2.0 lb	13.0
Calcium	29 g	0.4
Phosphorus	21 g	0.3
Salt	9 g	0.1

The use of protein supplements containing urea has held the cost of fortifying cattle rations with supplemental protein to a minimum. As a result, the large cost in cattle feeding is for the energy portion of the ration. Based on current feed prices, the following tabulation presents the cost of supplying energy, protein, minerals, and vitamin A to a 650-lb finishing yearling steer.

Daily amount (lb)	Ingredient	Cost/unit	Cost ($)	Percentage of total cost
13	Corn (No. 2)	$2.50/bu	0.58	66
18	Corn silage	$22.00/ton	0.20	23
1.5	48% Urea supplement (with minerals and vitamin A)	$130.00/ton	0.10	11

From the above calculation, it is obvious that the energy cost of the ration is the major cost, or 89% of the total. Furthermore, when one considers feed cost as representing approximately 70% of the total cost of a cattle finishing enterprise, then the cost of the energy portion represents 62% of the total cost of the enterprise.

Much of the energy consumed by beef cattle is wasted. Approximately 20 to 40% may be passed through the animal undigested in the feces; about 15 to 20% is lost in gases and urine, and as much as 30% is used in producing heat in the digestive process, leaving as little as 20% for body maintenance and weight gains. Some definitions of the energy terms commonly used to describe energy partitioning are given below.

A. Definitions of Terms

A large calorie or kilocalorie (kcal) is defined as the amount of heat necessary to raise the temperature of 1 liter of water from 15 to 16°C.

A megacalorie (Mcal) is equal to 1000 kcal; another term applicable here is the *Therm*. However, the latter term might be confused with the British thermal unit, or Btu (amount of heat required to raise the temperature of 1 lb of water 1°F).

Gross energy represents the heat of total combustion. This is also called the *heat of combustion*. The average heat of combustion for animals is listed below.

1 g of average carbohydrate produces 4.1 kcal
1 g of average fat produces 9.3 kcal
1 g of average animal protein produces 4.25 kcal
1 g of average vegetable protein produces 3.98 kcal
1 g of average mixed protein produces 4.1 kcal

Digestible energy, as the name implies, is that portion which the animal can digest. It is determined in digestion trials by subtracting fecal energy loss from gross energy intake.

Metabolizable energy, often referred to as available energy, is that left over after losses of energy in the feces, urine, and combustible gases. About 82% of digestible energy is metabolizable, that is, about 18% of digestible energy is lost in urine and gases.

Net energy is calculated by subtracting the heat increment energy from metabolizable energy. The so-called "work of digestion" energy is converted to heat and is not available for productive purposes. However, it is utilized to keep the animal warm and thus plays a critical role in cold weather. Metabolizable energy does not show the true potential of a feedstuff for productive purposes. The determination of net energy is tedious and expensive because it involves calorimetry or comparative slaughter methods to determine heat losses or energy retention. For these reasons, the net energy content of many feedstuffs has been estimated using equations relating metabolizable energy or TDN to net energy.

Productive energy is the energy remaining after maintenance requirements for energy have been met. It is utilized for productive work, tissue gain, or for production of milk, eggs, wool, and fur.

Total digestible nutrients (TDN) are a summation of all the potential energy digested by an animal. This is determined by the following equation.

$$\begin{aligned}\text{TDN} = {} & [\text{digestible fat} \times 2.25) + \text{digestible NFE} \\ & + \text{digestible fiber} + \text{digestible protein}]/100\end{aligned}$$

Digestible energy (DE) can be calculated from TDN by assuming that 1 kg of TDN = 4.4 Mcal of DE. Furthermore, ME can be calculated as 1 kg of TDN = 3.62 Mcal of ME.

B. Use of Energy in Determining Nutrient Requirements

The tables in Appendix IV use both the TDN and the net energy system for calculating beef cattle nutrient requirements. The National Research Council book (NRC, 1984) on beef cattle nutrient requirements uses both systems. The TDN system is based on estimates and observations coupled with limited performance data. However, because of the years of experience on which it has been based, it has become quite accurate in establishing nutrient requirements for a given set of conditions.

The net energy system is relatively new compared with the TDN system. However, because of its extreme accuracy in predicting both nutrient requirements and anticipated performance under a specified system of feeding, it has become widely accepted and used. The net energy system is based on two calculations, namely, net energy for maintenance (NE_m) and net energy for gain (NE_g). Perhaps the major advantage of separate net energy calculations for maintenance and for gain is that animal requirements do not vary when different roughage to concentrate ratios are used. The net energy system can be used to calculate the quantity of a given ration needed to meet an energy need or to formulate a diet to supply the needed concentration of energy per unit of dry matter. Alternatively, it can be used to predict the rate of gain when intake and energy concentration of the diet are known.

C. The Net Energy Method of Predicting Rate of Gain of Beef Cattle

This method is illustrated by the following problem. A 550-lb steer is fed dry shelled corn (1.9% of body weight, or 10.5 lb), 1 lb of high urea supplement, and corn silage to appetite (see Appendix IV, which indicates such an animal can consume a minimum of 13.2 lb of dry matter per day). If both the shelled corn and the high urea supplement contain 88% dry matter (DM), then those two ingredients will represent 10.1 lb of the dietary DM; this leaves 3.1 lb of DM to come from corn silage, or 10.3 lb of 30% dry matter corn silage. Potential rate of gain can be calculated as follows:

1. Determine the composition of the diet.

$$550 \times 0.019 \times 10.4 \text{ lb of corn (air-dry)} \times 88\% \text{ DM} = 9.20 \text{ lb of DM}$$

$$1 \text{ lb urea supplement} \times 88\% \text{ DM} = 0.88 \text{ lb of DM}$$

$$\text{Total DM from corn plus supplement} = 10.1 \text{ lb}$$

$$\text{Corn silage DM intake} = 13.2 \text{ lb (approx)} - 10.1 \text{ lb} = 3.1 \text{ lb}$$

	Pounds of DM	Percentage of DM
Yellow dent corn	9.2	70.23
Supplement	0.88	6.72
Corn silage	3.1	23.66
Total	13.1	100.00

2. Determine the energy content of the diet.

Calculate the NE_m and NE_g concentrations of the diet by multiplying the energy content of individual feedstuffs by the proportion of diet DM supplied by that feedstuff. The NE_m and NE_g (Mcal/lb) for corn are 0.99 and 0.68, and for corn silage they are 0.59 and 0.41. Assume that the NE_m and NE_g (Mcal/lb) of the supplement = 0.60 that of corn (0.70 and 0.43, respectively).

	Percentage of DM	Contribution (Mcal/lb) to	
		NE_m	NE_g
Yellow dent corn	70.23	0.70	0.48
Supplement	6.72	0.04	0.03
Corn silage	23.66	0.17	0.10
Total	100.00	0.91	0.61

The NE_m content of the diet is 0.91 Mcal/lb of DM; the NE_g content is 0.61 Mcal/lb of DM.

3. Determine feed required for maintenance.

From Appendix Table AIV.7, the NE_m requirement for a 550-lb steer is 4.84 Mcal/day. Feed required for maintenance = maintenance energy required divided by NE_m concentration of diet; therefore, 4.84 Mcal/0.91 Mcal of NE_m/lb = 5.3 lb of DM.

4. Determine energy available for gain to predict gain.

The energy available for gain is calculated by subtracting feed required for maintenance from total predicted DM intake and multiplying the remainder by the NE_m concentration of the diet; therefore (13.1 − 5.3) × 0.61 Mcal of NE_m/lb of DM = 4.76 Mcal of NE_m available for gain. From Table AIV.7, the predicted gain = 2.7 lb/day.

In some situations it may be desirable to limit growth rate by restricting feed intake. The net energy system can be used to estimate the amount of feed that should be offered for the desired weight gain. For the above example, suppose that the cattle should be fed to gain 2.0 lb/day. How much of the diet should be fed per day?

1. Estimate feed required for maintenance.

From Step 3 above; 5.3 lb of feed DM/day is needed for maintenance.

2. Estimate feed required for gain.

From Table AIV.7; NE_m required for gain = 3.33 Mcal. Feed required for gain is calculated by dividing NE_m required for gain by the NE_m concentration of the diet; 3.33/0.61 Mcal of NE_m/lb of DM = 5.5 lb of DM/day.

3. Estimate total feed required for gain.

Sum the maintenance feed and gain feed requirements; 5.3 + 5.5 = 10.8 lb of DM/day should be fed. Because the diet is 60% DM, one can calculate that 18 lb of as-fed diet should be offered daily in the form of 8.6 lb of corn, 0.83 lb of supplement, and 8.6 lb of corn silage per steer.

D. Sources of Energy

Among the nutrients there are two main sources of energy, namely, the carbohydrate materials plus ether extract or fat portions of the diet. Earlier in this chapter it was noted that energy has first priority. Therefore if energy is deficient, the protein of the diet also will serve as a source of energy. The use of dietary protein primarily as an energy source is expensive and inefficient. Thus the energy needs should be met primarily from the carbohydrate and fat portions of the diet.

1. Carbohydrates

Carbohydrates are routinely classified as belonging to one of several categories including monosaccharides (glucose, fructose, galactose), disaccharides (sucrose, maltose, and lactose), and polysaccharides (starch, glycogen, and cellulose). This represents primarily a chemical classification of the carbohydrate family and is quite applicable in monogastric nutrition. However, for ruminants, a more relevant classification involves dividing carbohydrates into the nitrogen-free extract (NFE) (or nonfiber carbohydrates) and cell wall carbohydrates (or fibrous carbohydrates). The NFE fraction includes more ruminally soluble and rapidly degradable carbohydrates (monosaccharides, disaccharides, and starch) whereas the cell wall fraction includes less soluble carbohydrates that are degraded at varying rates and to varying extents in the rumen. Under this system, cell wall includes cellulose, hemicellulose, pectins, and lignin. The latter is not a true carbohydrate, but is included because it is almost always associated with hemicellulose and cellulose.

a. Nitrogen-Free Extract or Nonfiber Carbohydrates. The relatively soluble carbohydrates are classified as the NFE and include the mono- and disaccharides plus the starches, and perhaps a part of the hemicelluloses, based on their relative solubility and digestibility. There is no practical method for exact determination of the NFE portion of feedstuffs. However, it can be determined mathematically by subtracting all the other determinations from 100.

$$100 - (\text{water} + \text{crude fiber} + \text{ether extract} + \text{crude protein} + \text{ash}) = \text{NFE}$$

For feeding purposes this calculation has proven satisfactory, although it is obvious that it is not too accurate and errors can be introduced with each variable.

NFE is of prime consideration in cattle feeding because it represents the most important energy source in the finishing of beef animals destined for slaughter. The primary source of NFE in finishing diets is the starch contained in feed grains such as corn, milo, barley, wheat, and oats.

Cattle saliva contains no enzyme capable of degrading starch so dietary starch passes to the rumen unscathed. The rate of starch fermentation in the rumen varies extensively by grain type and processing method. The extent of ruminal starch digestion is a function of the rate of digestion and the rate of passage of starch-containing particles from the rumen. In general, processing methods that increase the surface area of starch granules or disrupt the starch–protein matrix will increase ruminal starch digestion (Table 1.2). More discussion is provided on this subject in Chapter 6.

In the small intestine, amylases break down starches and disaccharides into 6-carbon sugars. These products are absorbed into the bloodstream, primarily as glucose. They probably combine with phosphorus for absorption across the villi

of the small intestine. Not all of the sugars proceed across the villi at the same rate. Galactose is absorbed most rapidly, followed by glucose and fructose.

b. Crude Fiber or Cell Wall Carbohydrates. The second classification is crude fiber, which is defined as that nonmineral portion of the feedstuffs which is not soluble in weak acid or weak alkali. A more specific method of fiber fractionation involves the use of extraction procedures to partition cell wall carbohydrates into fractions which are soluble in neutral or acid detergents. These procedures were developed by Van Soest and co-workers at Cornell University; the Van Soest fiber analysis system is the preferred method of expressing the fiber content of feeds, particularly for dairy feeding. However, feed tags continue to provide the crude fiber content of feeds, so a brief description of the crude fiber assay follows.

For crude fiber determination, fat and water are removed from a feed sample which is then boiled for 30 min with weak sulfuric acid (1.25%) and then for 30 min with weak sodium hydroxide (1.25%). These procedures ostensibly simulate exposure of fiber to the digestive processes occurring in the stomach and small intestine. Extraction in weak acid and alkali removes proteins, soluble sugars, and starches, leaving lignin, cellulose, other complex carbohydrates, and minerals. The loss on ignition of the remaining material is defined as crude fiber.

The Van Soest method of fiber analysis is the preferred method of defining the chemical nature of cell wall carbohydrates. The methods for determining the neutral detergent fiber (NDF: cellulose, hemicellulose, lignin, insoluble ash), acid detergent fiber (ADF: cellulose, lignin, ash), acid detergent lignin, and other cell wall fractions are outlined in detail in the USDA Handbook by Goering and Van Soest (1970). Some of the methods have also been clarified in more recent literature (Van Soest *et al.*, 1990). The NDF content of feedstuffs has been shown to be related to the potential intake of forages whereas the ADF and lignin contents of feedstuffs are potential indicators of forage digestibility. One shortfall of this scheme is that viscous polysaccharide fibers, such as pectins, gums, and mucilages, are not recovered as cell wall carbohydrates. Thus, for some feedstuffs that are high in these fractions, total fiber content will be underestimated. Also, there is the potential for overestimation of cell wall content because of starch and nitrogen contamination of cell wall residues; however, procedures can be used to minimize or correct these problems.

c. Carbohydrate Metabolism. In general, there is no net absorption of glucose from the portal vein, indicating that visceral tissues extensively metabolize glucose for energy or for the synthesis of visceral lipids, mucopolysaccharides, and triacylglycerides. However, exogenous glucose supply can spare the synthesis of glucose by the liver and improve energy status. During positive energy balance, carbohydrate is deposited in the liver as glycogen. During such

times, glycogen may compose 10% of liver weight, but stores may fall to practically zero during carbohydrate depletion. Skeletal muscle also stores glycogen and muscle may contain up to 2% glycogen.

The immediate fate of glucose is governed by the level of at least two hormones, namely, insulin and epinephrine, more commonly called adrenaline. Most researchers believe insulin accelerates conversion of glucose to glycogen and carbohydrate oxidation in the liver and muscles, and that adrenaline increases the rate of hydrolysis of liver glycogen to glucose and increases the conversion of muscle glycogen to hexose phosphate.

The most important step in carbohydrate metabolism is the oxidation of glucose to CO_2 and H_2O with the release of energy. The following equation offers the net reaction in a simplified form.

$$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6H_2O + 673 \text{ cal}$$

Glucose is catabolized to pyruvate, which in turn enters the tricarboxylic cycle. By a series of reactions in which as many as a dozen enzymes participate, one molecule of glucose yields two molecules of 3-carbon pyruvate. Under anaerobic conditions, such as in skeletal muscle, pyruvate is oxidized to lactic acid, whereas under aerobic conditions oxidation of pyruvate follows the equation given above.

d. Conversion of Carbohydrates to Fat. The nutritional basis of fattening livestock for slaughter is that carbohydrate is readily converted to adipose (fat) in the animal body. This necessitates the formation of two types of compounds, namely, glycerol and fatty acids. Glycerol may arise from glucose metabolism, possibly from phosphoglyceraldehyde, a product in carbohydrate metabolism.

Acetyl coenzyme A provides the starting point for fatty acid synthesis. First, carboxylation of acetyl coenzyme A takes place, and then through a series of complicated condensations, 2-carbon fragments are attached to form the typically even numbered carbon chain fatty acids. Fatty acid synthesis is minimal in the liver but extensive in adipose tissue. Most fatty acids synthesized by adipose tissue have more than 16 carbons, with 16- and 18-carbon saturated fatty acids predominating. The mammary gland synthesizes fatty acids having from 4 to 16 carbons. It is important to note that linoleic, linolenic and arachidonic acids are essential fatty acids which cannot be synthesized by ruminants and therefore must be supplemented in the diet.

2. Fats

Fats or lipids are a group of naturally occurring substances characterized by their insolubility in water and their solubility in solvents such as ether, chloroform, boiling alcohol, and benzene. The lipid group includes not only the true fats but also materials which are related chemically (lecithin) and materials

which have comparable solubility properties (cholesterol, waxes). The true fats are of interest not only because they are a concentrated source of energy (2.25 times more energy than carbohydrates) but also because a number of vitamins are associated with fat (fat-soluble vitamins, A, D, E, and K). In addition, even though fat is not considered as an indispensable nutrient per se, nutritionists recognize that certain fatty acids are essential (linoleic, linolenic, and arachidonic acids).

Of the nutrients in beef cattle nutrition, fat is generally found in small quantities, except when fat is added to the diet. Even when fat is added to the diet, it usually represents no more than from 3 to 5% of the total DM. Common feedstuffs contain fairly low levels of fat, ranging from practically none up to 2% in hays, 4 to 5% in grains, 7 to 10% in distillery by-products, 13% in rice bran, and up to 98% in oils and tallows. Thus a diet based on hay, corn, and oil meal contains less than 4% fat. However, 4% of digestible fat will contain the energy equivalent of 9% of digestible carbohydrate or protein due to its concentrated energy.

In the rumen, fat is hydrolyzed to glycerol and constituent fatty acids. Unsaturated fatty acids are hydrogenated by the ruminal microorganisms to form saturated fatty acids. About three-fourths of the lipids arriving at the abomasum are of dietary origin, while the remaining lipid is derived from phospholipids of microbial origin. In the small intestine, bile plays a role in forming fat micelles which contact microvilli of the intestinal mucosa. Free fatty acids are absorbed in the upper small intestine and travel via lymphatic circulation in the form of chylomicrons, which consist predominantly of triglycerides and smaller amounts of phospholipids, free fatty acids, cholesterol, and cholesterol esters. The fatty acids found in chylomicrons are used as energy substrates by body tissues or as substrates in the synthesis of adipose or milkfat. Although fat may be deposited in various portions of the animal body, it is stored primarily (1) in intramuscular connective tissue, (2) in the abdominal cavity, and (3) in subcutaneous connective tissue.

When fat is to be used as a source of energy, the first reaction is hydrolysis to glycerol and the three constituent fatty acids. Glycerol enters the tricarboxylic acid cycle; the fatty acids are oxidized to CO_2 and water via β-oxidation in which oxygen acts upon the β carbon of the fatty acid moiety, eventually resulting in the release of a 2-carbon fragment.

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2

Vitamin Requirements of Beef Cattle

Tilden Wayne Perry

Perhaps the most universally accepted definition of vitamins is that suggested by Rosenberg (1945).

> Vitamins are organic compounds which are required for normal growth and maintenance of life in animals, including man, who, as a rule, are unable to synthesize these compounds by available processes that are independent of the environment other than air, and which compounds are effective in small amounts, do not furnish energy and are not utilized as building units for structure of the organism, but are essential for the transformation of energy and for the regulation of the metabolism of structural units.

There is a biblical reference to the fact that "cattle were not able to see because there was no green grass for them to eat." So possibly an awareness of this fact may represent some of the very earliest knowledge of the science of nutrition. However, there is a long period from that biblical beginning until the four decades between 1910 and 1950 when so much knowledge concerning vitamins was uncovered. It is now more than four decades since the last recognized vitamin—vitamin B_{12}—was discovered (1948).

Generally, the vitamins are classified into "fat-soluble" and "water-soluble" groupings. This method of classification is largely a physical one and does not reveal much more about the vitamins than their solubility characteristics. Fat-soluble vitamins contain only carbon, hydrogen, and oxygen, while the water-soluble vitamins—except inositol and vitamin C—also contain nitrogen, sulfur, or cobalt.

It is generally accepted that animals with a developed rumen can synthesize all of the recognized water-soluble vitamins if their diet contains all the elements needed. A good example of this effect is for a cobalt deficiency, in which cattle are unable to synthesize vitamin B_{12}, for which cobalt is an essential constituent. Such cattle will show varying symptoms of anemia, since vitamin B_{12} is needed for normal levels of hemoglobin. Veterinarians often administer supplemental B vitamins as a part of a "stress pack" when ruminant animals need special attention, considering that a less than normal rumen may not be capable of synthesizing B vitamins at a normal rate.

I. FAT-SOLUBLE VITAMINS

A. Vitamin A

The ultimate functions of vitamin A in animals can be brought about by several natural and synthesized compounds.

One grouping of nine compounds is the carotenoids, each of which contains 40 carbon atoms, and which are the forms occurring in plants. The carotenoids possess no vitamin A activity, but can be converted to physiologically active vitamin A in varying degrees in accordance with the type of carotene and the type of animal consuming it. Since the carotenes must be converted to vitamin A before they have vitamin A activity, they are called provitamins A. The carotenes occur in association with chlorophyll in plants. The carotenes do not occur in more than token quantities in animals, although some are found in fat deposits, milk and butter, blood, liver, corpus luteum of cows, and testes of bulls. The carotenes occurring in green and yellow plant materials are a most important source of vitamin A for animals. Typically, green pasture, silages, hay, yellow corn, carrots, and pumpkin represent cattle feed sources richest in the carotenes.

The carotenes are destroyed by exposure to oxygen, once the plant producing it has been harvested. Naturally, this is not an instantaneous result, but rather occurs over a period of time. As an example, yellow corn may have lost practically all of its carotene within 1 year after it was harvested and stored where oxygen was available (McDonald *et al.*, 1966). In contrast, silages—which are stored under anaerobic conditions—may retain a major portion of their original carotene for many months. Green hay curing in the swath may lose up to one-half of its carotene (vitamin A potential) in 1 day of exposure to the sunlight and oxygen—it may lose practically all of its carotene if exposed to rain as well as sunlight. Mature, overripe plant materials have greatly reduced levels of carotene.

Species of animals vary in their ability to convert carotene to vitamin A. The rat quite efficiently converts carotene to vitamin A, whereas this process is limited in cats. Furthermore, there is within-species variation in that capability, i.e., Holsteins convert carotene to vitamin A quite efficiently, whereas Guernseys are much less efficient. Research at the Purdue Experiment Station (Perry *et al.*, 1957) first demonstrated that finishing steers receiving 20 mg carotene per day suffered typical vitamin A deficiency symptoms, while cattle fed similar diets plus 20,000 to 30,000 international units (IU) of crystalline vitamin A per head, daily, gained weight approximately 25% more rapidly and had no vitamin A deficiency symptoms. These data indicate that finishing cattle do not convert carotene to vitamin A very efficiently.

Vitamin A, per se, has not been identified in plants, and occurs only in animals. The most potent natural sources of vitamin A include various liver oils.

Among fish, for example,vitamin A potency per gram of liver oil ranges from 65 IU for haddock to 600,000 for black sea bass. Cod liver, perhaps the most commonly used fish liver source of Vitamin A, contains about 600 IU per gram. Because the liver oils are so highly unsaturated, they are subject to oxidation which, in turn, rapidly destroys their vitamin A potency. Therefore, when stabilized synthetic sources of vitamin A became available, the use of fish liver oil as sources of vitamin A declined rapidly.

Vitamin A plays many critical roles in the animal body. Vitamin A is involved in a generalized maintenance of epithelial tissue ("generalized" because it is not recognized how this function is accomplished). In the absence of adequate vitamin A in the body, the epithelial tissues tend to keratinize (Wolbach and Howe, 1925) and thus lose most of their useful functions. This effect is found in the alimentary, genital, reproductive, respiratory, and urinary tracts, each of which is lined with epithelial tissue. Such altered characteristics make the affected areas more susceptible to infections. Thus, colds and pneumonia are typical secondary effects of a vitamin A deficiency. However, greater than optimal levels of vitamin A should not be proposed as a deterrent to infections. A vitamin A deficiency also may result in reproductive problems, less rapid weight gain, and impaired vision. Vitamin A is a component of normal bone development through the osteoblasts of the epithelial cartilage. Thus, if a vitamin A deficiency exists, abnormal bone formation will result.

The vitamin A requirements of beef cattle may be met in part by administration of provitamin A (carotene) plus supplemental crystalline vitamin A, either by injection (Fig.2.1) or orally. International standards for vitamin A are based upon the ability of the rat to convert beta-carotene to vitamin A. However, beef cattle convert carotene to vitamin A much less efficiently than do rats. For rats, 1 mg of beta-carotene is equivalent to 1667 IU of vitamin A, but for beef cattle it is proposed that 1 mg of beta-carotene is equivalent to only 400 IU of vitamin A.

Under practical feeding conditions it is desirable for cattlemen to recognize the following: (1) in drought years, with prolonged consumption of bleached grasses or hay, or when the background of purchased cattle is unknown and they appear unthrifty, body stores of vitamin A (primarily the liver) might be suboptimal; (2) the carotene content of dried or sun-cured forages decrease upon storage with the rate of such destruction depending upon factors such as temperature, exposure to air and sunlight, and length of storage; (3) vitamin A and carotene destruction occurs due to the processing of feeds with steam and pressure, or when they are mixed with certain oxidizing materials such as minerals.

Growing and finishing cattle require 1000 IU of vitamin A per pound of dry diet (2200 IU/kg), pregnant heifers and cows, 1270 IU/lb (2794 IU/kg), and lactating cows and bulls, 1770 IU/lb (3900/kg) (National Research Council, 1984). Intramuscular injection of emulsified vitamin A at a level of one million IU will provide sufficient vitamin A to prevent deficiency symptoms for about 3

Fig. 2.1 Intramuscularly injected vitamin A ensures uniform dosage for an extended period of time.

months in growing or breeding beef cattle (Table 2.1). Such injected vitamin A is transferred to the liver for storage and parcelled out only as needed by the body.

Vitamin A deficiency symptoms for all species of animals are almost impossible to identify except where deficiencies are very marked. The first observable vitamin A deficiency symptom is decreased growth, which also could be the result of a number of factors, including genetics and energy or protein deficiency. The role of vitamin A in promoting growth (Table 2.2) is not understood except that it is involved in the activity of bone cell formation at the epiphyseal cartilage.

In vitamin A deficiency of rather long duration, several visual impairment conditions may result. Night blindness due to inability to regenerate visual purple is the result of a vitamin A deficiency; inflammation of the eyes due to the drying up of the tear ducts and thus inability to wash the eyes also is due to a vitamin A deficiency.

Probably the most accurate indicator of a borderline vitamin A deficiency is an analysis of the blood plasma of several animals from the group. A level of less than 40 μg of vitamin A/100 ml of blood plasma indicates vitamin A deficiency (Table 2.3).

B. Vitamin D

It can be assumed that beef cattle usually receive sufficient vitamin D from exposure to direct sunlight or from sun-cured feedstuffs. In exposure to sunlight,

TABLE 2.1

Injectable versus Oral Vitamin A for Fattening Steer Calves[a]

	Method of administering vitamin A			
	Control (none)	20,000 IU per day, orally	1 million IU injected initially	6 million IU injected initially
Daily gain				
lb	1.76[b]	2.07[c]	2.00[c]	1.94[c]
kg	0.80	0.94	0.91	0.88
Feed per unit gain	9.4	8.5	8.5	8.8
Blood serum data				
Vitamin (μg/100 ml)				
Initial	38	42	32	41
167 days	24	59	27	48
210 days	21[d]	49[e]	16[d]	40[e]
Carotene (μg/100 ml)				
Initial	105	154	133	94
167 days	134	100	124	105
210 days	104	85	111	107
Final liver data				
Vitamin (μg/gm)	3[d]	15[e]	2[d]	12[e]
Carotene (μg/gm)	10[d]	19[e]	13[d]	19[e]

[a]Average initial weight, 540 lb (245 kg), 210 days. Data from Perry *et al.* (1962).
[b,c]Significantly different ($p < 0.05$).
[d,e]Significantly different ($p < 0.01$).

the ultraviolet rays of sunlight convert 7-dehydrocholesterol contained in the skin to active vitamin D. In the case of animals covered with hair or fur, oil from the skin —and that which gets onto the hair or fur—is irradiated by the sunlight, and as such animals lick themselves, or each other, they obtain vitamin D. However, because there may be situations in which cattle are not exposed to sufficient sunlight, as in closed confinement, a discussion of the role of vitamin D is included.

Since vitamin D plays a role in the metabolism of calcium and phosphorus, one must postulate that the principal function of vitamin D is involved intimately in the utilization of calcium and phosphorus. Vitamin D is critical for normal adsorption of calcium and phosphorus from the gut.

The body has some vitamin D storage capability, mainly in the liver and, to a limited extent, in the lungs and kidneys.

Deficiency of vitamin D in growing animals results ultimately in external symptoms characterized by deformed bones and excess deposit of cartilage in the usual areas of bone growth. The blood level of calcium and/or phosphorus is lowered but the level of phosphatase is increased. There is a widening of the

TABLE 2.2

Effect of Level of Supplemental Vitamin A on Growth Rate of Beef Cattle[a]

Vitamin A per steer per day (IU)	Daily gain[b]		Daily feed		Feed per unit gain
	lb	kg	lb	kg	
		No alfalfa meal[c]			
0	1.82	0.83	16.8	7.6	9.2
10,000	2.18	0.99	18.6	8.4	9.6
20,000	2.39	1.09	20.3	9.2	8.5
30,000	2.21	1.00	19.0	8.6	8.6
40,000	2.33	1.05	19.7	9.0	8.5
50,000	2.36	1.07	19.5	8.9	8.3
		10% sun-cured alfalfa meal[c]			
0	2.15	0.98	18.6	8.4	8.6
10,000	2.43	1.10	19.4	8.8	8.0
20,000	2.52	1.14	20.6	9.4	8.2
30,000	2.46	1.12	20.5	9.3	8.3
40,000	2.46	1.12	20.0	9.1	8.1
50,000	2.47	1.12	19.7	9.0	8.0

[a]Average initial weight, 470 lb (214 kg), 256-day trial. Data from Perry *et al.* (1962).

[b]Feeding of all levels of supplemental vitamin A resulted in increases ($p < 0.01$) in gain. Cattle fed 10% alfalfa gained more rapidly ($p < 0.01$) than cattle not fed alfalfa.

[c]Control diet (high corn) contributed 16.8 mg carotene per day; sun-cured alfalfa diet contributed 45 mg carotene per day.

epiphyseal junction in severe or prolonged vitamin D deficiency and the tension of the muscles will cause a bending and twisting of the long bones to give the characteristic deformity of the bone. There is enlargement at the ends of the bones due to the deposit of excess cartilage, giving the characteristic "beading" effect along the sternum at the point of attachment of the rib bones. Rickets is fairly common in calves and is characterized by decreased growth, stiffness, enlarged joints, and arching of the back (Table 2.4).

In mature animals a condition of osteomalacia or, literally, a wearing away of the bones characterizes a prolonged vitamin D deficiency. If the deficiency is prolonged, the bones will become sufficiently depleted of calcium and phosphorus that they will fracture.

There are essentially two sources of vitamin D: liver oils and products that have been exposed to ultraviolet radiation. Most plants contain a sterol known as ergosterol, which when irradiated by ultraviolet light is converted to calciferol, an active form of vitamin D. Several years after this had been recognized, subsequent research demonstrated that calciferol was not very active for poultry, but that irradiated 7-dehydrocholesterol (animal source) was seven times as

TABLE 2.3

Effect of Vitamin A and Carotene Intake on Blood Plasma Levels and Liver Storage[a]

Vitamin A per steer, per day (IU)	Blood plasma (μg per 100 ml) Vitamin A: Initial	Vitamin A: 107 days	Vitamin A: 256 days	Carotene: Initial	Carotene: 107 days	Carotene: 256 days	Liver vitamin A per gram
			No alfalfa[b]				
0	56	26	11	47	64	40	4
10,000	60	49	37	50	68	57	7
20,000	57	59	45	48	56	45	22
30,000	50	59	53	40	44	32	49
40,000	58	69	52	57	43	34	64
50,000	48	68	59	54	51	35	120
			10% sun-cured alfalfa meal[b]				
0	54	39	16	51	108	51	3
10,000	49	65	34	45	92	59	8
20,000	54	68	49	37	66	51	23
30,000	50	76	64	46	54	47	55
40,000	50	77	65	38	60	39	80
50,000	53	72	61	46	53	38	146

[a]Perry *et al.* (1962).
[b]High energy diet contributing 16.8 mg carotene per day; those containing 10% sun-cured alfalfa meal contributed 45 mg carotene per day.

active for poultry as calciferol. However, that discrepancy does not exist for cattle. This resulted in categorizing vitamin D into D_2, the plant source, and D_3, the animal source.

The vitamin D requirement for beef cattle is 125 IU/lb dry diet (275 IU/kg) (National Research Council, 1984). The IU is defined as 0.025 μg of cholecalciferol (D_3), or its equivalent.

TABLE 2.4

Composition of Normal and Rachitic Bones[a]

	Water	Ash	Organic matter	Calcium	Phosphorus
Normal rib	14–33	40–47	27–39	16–18	5–8
Rachitic rib	42–66	8–32	21–22	3–12	1–6

[a]Data are percentage of dry fat-free matter. Hess (1929).

C. Vitamin E

Vitamin E has wide distribution in nature; especially rich sources are the germs of seeds. The 1984 NRC booklet on beef cattle indicates, "normal cattle diets apparently supply adequate amounts for adult cattle, and even diets very low in vitamin E do not affect growth, reproduction, or lactation when fed to four generations." There appears to be a partial overlap in the functions of vitamin E and selenium, but most researchers agree there are some requirements of each that cannot be met by the other.

Since vitamin E is especially susceptible to oxidative destruction, various methods of processing and/or storage may result in varying degrees of destruction of naturally occurring vitamin E in feedstuffs. Its role in beef cattle will be discussed below.

It is perhaps unfortunate that vitamin E has been related so closely to reproduction, since apparently that aspect of vitamin E is critical only to the rat. Proof has not been presented to indicate that a vitamin E deficiency affects reproduction per se in any species with the exception of the rat. Yet many "shy breeding" and sterile bulls, rams, and stallions have been administered copious amounts of vitamin E in the hopes that somehow this would cause them to become fertile or sexually aggressive. The most common lesion attributed to a vitamin E deficiency is a deterioration of the striated muscle. Thus, muscular dystrophy is the most common manifestation of a vitamin E deficiency in farm animals. This condition is known as "white muscle disease" in young calves. Vitamin E is an effective antioxidant because it is so readily oxidized itself. This capability of vitamin E has perhaps been overplayed in an attempt to assess its function. However, as an antioxidant, it prevents peroxidation of unsaturated fatty acids to form free radicals and hyperperoxides, which destroy a part of the cell.

The body has tremendous potential for storage of vitamin E. Therefore efforts to study deficiency symptoms have been impeded by such body stores, which can prevent true symptoms of a deficiency from appearing for long periods of time.

Vitamin E is one of the fat-soluble vitamins. The richest natural source of vitamin E is wheat germ oil. All cereal grains, legumes, and nuts are excellent sources of vitamin E. There are at least three forms of vitamin E, namely, α-, β-, and γ-tocopherol. α-Tocopherol is the most potent of the three. The tocopherols are resistant to heat but they are readily oxidized.

The National Research Council makes no quantitative recommendation for vitamin E requirements for beef cattle, except that "estimates of the requirement for younger calves range from 15 to 60 IU (mg) of *dl* α-tocopherol acetate per kilogram of dry diet (7 to 27 IU/lb)." The NRC bulletin goes on to point out that under most conditions, natural feedstuffs appear to supply adequate α-tocopherol for adult cattle.

D. Vitamin K

The fourth fat-soluble vitamin is vitamin K, which derived its name from the Danish word koagulation and was discovered by Henrik Dam.

Vitamin K is concerned primarily with blood coagulation, and in certain situations where the action of vitamin K is inhibited, increased clotting time of the blood is encountered. This should not be confused with hemophilia, which is a condition in males inherited through the mother that is characterized by a tendency to bleed excessively.

Vitamin K is required for the formation of prothrombin, plus possibly other related proteins, in the liver. In the mechanics of blood clotting it is suggested that thromboplastin, released from damaged tissue, in the presence of calcium ions, converts prothrombin into thrombin. Once thrombin has been formed it converts soluble fibrinogen of the blood plasma into insoluble fibrin, which is the clot. Thus, any interference with thrombin formation, for example, will in turn slow down blood clotting.

Vitamin K is quite prevalent in nature, especially in green leaves; it occurs abundantly in seeds, and much less abundantly in fruits and roots. Vitamin K is synthesized in the rumen. However, the problem that might exist relative to vitamin K adequacy in cattle nutrition is the matter of an anti-vitamin K substance known as dicumarol. Spoiled sweet clover contains dicumarol which, when consumed, serves as an anti-metabolite, blocking the action of vitamin K in forming prothrombin.

Since vitamin K is a normal dietary constituent as well as a normal rumen synthesis product, it is generally accepted that there is no supplemental dietary need for cattle except at such times as when they might be consuming dicumarol. The NRC does not list a vitamin K requirement for beef cattle.

II. WATER-SOLUBLE VITAMINS

Water-soluble vitamins often are assumed to be synthesized in sufficient quantities by cattle with a developed rumen. Beef calves normally nurse until they reach an average age of 6 or 7 months; the milk received by nursing calves is an excellent source of all the water-soluble vitamins. Rumen development is initiated very early in the calf's life and the consumption of roughages enhances such development so that by the time a calf is weaned, its rumen is functioning. Such animals as well as more mature animals—including young herd replacement stock, breeding stock, and feeder cattle—will manufacture sufficient water-soluble vitamins to meet their physiological needs under normal conditions. However, during times of stress the normal functions of the rumen may be

interfered with such that there may be a relative deficiency of at least some of the B-vitamins.

A. Thiamin

Under certain conditions a relative thiamin deficiency may develop. Although thiamin (vitamin B_1) should be synthesized in sufficient quantities in the rumen, a condition known as polioencephalomalacia (often called "circling disease" because of that characteristic in affected cattle) may develop. This condition may be alleviated in a matter of 1 h or less by the intramuscular injection of thiamin. Under the effect of this malady, cattle seem not to see as they are circling, and will run into posts or any person that may be within their circling path. Circling disease seems to occur most often in feeder cattle being fed corn silage—thiaminase, an enzyme which destroys thiamin, is found often in corn silage. Sudden death will occur in a majority of affected cattle if they are not treated promptly. Because corn silage is such an excellent roughage-energy feed for beef cattle, and because the malady does not occur too often, cattle feeders should not abandon the practice of feeding corn silage to cattle.

B. Vitamin B_{12}

Although vitamin B_{12} should be synthesized in the rumen in adequate quantities, much research has demonstrated that supplemental vitamin B_{12} may cause improved growth performance in feeder cattle on high concentrate diets. The ability of cattle to synthesize vitamin B_{12} is probably borderline at best.

C. Other B-Vitamins

Veterinarians often administer complex mixtures of several of the B-vitamins to new feeder cattle, or to cattle well-established in the feedlot who appear to have developed digestive disorders. This practice may have merit, but it has not been proven.

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3

Mineral Requirements of Beef Cattle

Tilden Wayne Perry

I. INTRODUCTION

The total mineral, or ash, content of the animal body represents a very small percentage of the total dry matter. Furthermore, several factors such as age of the animal and percentage of fat carried by the body affect the percentage composition. Reid and co-workers (1955) expressed body composition of the bovine on a "fat-free" basis, minus the contents of the digestive tract. On this basis, the composition was 72.9% water, 21.6% protein, and 5.3% ash. In addition, there is a very small amount of carbohydrate, which is found primarily in the liver, muscle, and blood.

Missouri researchers (Hogan and Nierman, 1927) analyzed the bodies of steers of varying ages and characterized the mineral composition of the body for several mineral elements as follows: calcium, 1.33%; phosphorus, 0.74%; sodium, 0.16%; potassium, 0.19%; chlorine, 0.11%; magnesium, 0.04%; sulfur, 0.15%. In addition to those listed, there are a host of other mineral elements found in the bovine body in very minute quantities. For example, Perry and co-workers (1976a) analyzed numerous cattle hair samples for selenium content and reported a level of 0.38 ppm selenium, which would be equivalent to less than one ten-thousandth of 1% selenium.

Approximately 90% of the calcium and 70% of the phosphorus, plus magnesium, sulfur, sodium, and chlorine, are utilized in the bone and in cartilaginous organic matrix. Reasonably large quantities of phosphorus, potassium, and sulfur are involved in muscle and gland tissues; sodium, potassium, and chlorine, plus other elements, are in solution in the body fluids which establish pH and are involved in secretions, osmotic pressure, and the irritability of the nerves and contractility of the muscles.

Beef Cattle Feeding and Nutrition,
Second Edition

II. ESSENTIAL MAJOR MINERAL ELEMENTS

A. Calcium

Calcium is the most abundant mineral element in the body; 99% is found in the bones and teeth and 1% is in various soft tissues. Normal blood plasma contains 10–12 mg per 100 ml, but this level may fall as low as 5–7 mg per 100 ml under conditions of severe deficiency. Calcium is involved in a number of roles in the body. It is required for (a) normal bone and teeth formation and maintenance, (b) normal blood clotting, (c) muscular contraction, (d) the regulation of the heartbeat, (e) secretion of certain hormones, and (f) milk production.

The most characteristic symptoms of a calcium deficiency are rickets (in the developing animal) and osteomalacia, or "wearing away of the bones" (in mature animals). However, both of these symptoms represent advanced acute deficiency and rarely are observed. Milk diets for the young and typical roughage diets fed to brood cows normally contain sufficient calcium to meet at least minimal needs. Most feeding grains are extremely low in calcium (corn, 0.02%; barley, 0.05%; milo, 0.03%; wheat, 0.05%, compared to grass-legume hay, 0.47%). Therefore, a calcium deficiency for beef cattle may most often be anticipated with finishing cattle on high-energy rations. Unless supplemental calcium is provided, one may expect poorer gains, poorer digestibility of feedstuffs, and even occasional tetany. Blood assays will show lowered calcium in the range of 5–7 mg per 100 ml.

In addition to its structural role in bone and tooth formation, calcium plays several metabolic roles. Furthermore, the roles of both calcium and phosphorus in the bone are not strictly structural. The bones serve as metabolic pools for these elements, which may be drawn upon by the soft tissues of the body as needed. Thus, in times of late gestation or in lactation, calcium and phosphorus may be drawn from the bone metabolic pool to meet needs not satisfied by dietary intake.

Calcium is absorbed actively from the duodenum and jejunum. The solubility of calcium compounds, and hence the absorption of calcium, is favored by acid conditions and hindered by alkaline conditions in the small intestine. Thus, most calcium is absorbed in the proximal portion of the duodenum. Calcium absorption is depressed by fluorine (Ramberg and Olson, 1970), is greater in younger than older animals (Hansard *et al.*, 1954), is greater during periods of low calcium intake than when calcium intake is high, and is depressed during a lack of vitamin D (DeLuca, 1974). Strontium absorption and metabolism parallel those of calcium (Comar *et al.*, 1961).

Several changes occur in response to a lowering of blood plasma calcium. First, parathyroid hormone is released, which stimulates the production of 1,25-dihydroxy cholecalciferol, a metabolically active form of vitamin D. This causes

TABLE 3.1

Calcium and Phosphorus Requirements of Beef Cattle[a]

Feeding situation	Daily gain	Weight range	Dry matter (%) Calcium	Phosphorus
Finishing cattle				
lb	2.4–2.7	400–600	0.68–0.46	0.26–0.24
kg	1.1–1.2	182–273		
Finish yearling				
lb	2.6–3.0	650–900	0.50–0.35	0.25–0.20
kg	1.2–1.4	295–409		
Finish yearling				
lb	2.6–3.0	900–1100	0.30–0.32	0.23–0.19
kg	1.2–1.4	409–500		
Growing heifers				
lb	2.2–2.5	450–900	0.55–0.32	0.26–0.20
kg	1.0–1.1	204–409		
Beef cows				
Dry, pregnant				
lb		800–1300	0.20	0.20
kg		363–591		
Lactation				
Average		800–1300 lb	0.28	0.23
Superior		800–1300 lb	0.37	0.27

Note. For more detailed requirements see Appendix IV.
[a]National Research Council (1984).

increased production of calcium-binding protein in the intestine, and in conjunction with the parathyroid hormone it increases calcium resorption from the bone and increases phosphorus loss in the urine. If blood plasma calcium levels become elevated, calcitonin is produced and parathyroid hormone production is inhibited, thus intestinal calcium absorption and bone resorption of calcium are slowed.

Although the proper ratio of calcium to phosphorus is critical in affecting absorption of both, it may be less critical in beef cattle than in most animals. Research has shown that beef cattle can tolerate calcium to phosphorus ratios as wide as 7:1 without detrimental effect. However, the optimum ratio is probably from 2:1 to 1:1 (Wise *et al.*, 1963). Smith *et al.* (1964) presented data indicating that doubling the calcium level in the diet from 0.25 to 0.50% interfered with zinc utilization (Table 3.2).

At parturition, dairy cows exhibit a drop of 1 to 2 mg calcium/100 ml plasma calcium. Milk fever may develop in dairy cows if plasma calcium drops below 5 mg/100 ml (Jacobson *et al.*, 1975). However, milk fever would be anticipated

TABLE 3.2

Effect of Dietary Calcium Levels on Serum and Hair Zinc[a]

	Dietary level of calcium	
	0.25%	0.50%
Number of lots	4	4
Number of cattle	24	24
Serum zinc (μg/100 ml)		
Initial	130	135
Final (162 days)	213	188
Hair zinc (μg/gm)		
112th day	212	174

[a] Data from Smith *et al.* (1964).

rarely in beef cows because of the disparity in milk production between beef and dairy cows.

The bones serve as metabolic pools for calcium and phosphorus, even in old age; thus, if dietary levels of calcium and phosphorus are not adequate, and if this state is prolonged, a condition known as osteomalacia develops due to a withdrawal of calcium and phosphorus that is greater than that deposited.

Calcium plays a role in blood coagulation. The calcium in the blood is found in the plasma. In the blood clotting process, calcium apparently forms a complex with prothrombin which is acted upon by thromboplastin to form thrombin; thrombin then acts on soluble fibrinogen to form fibrin, which is the blood clot. Without calcium, blood will not clot. (Actually this effect is employed to keep blood liquid, in which oxalate is introduced to tie up calcium.)

Recommended dietary calcium levels for various beef cattle situations are given in Appendix IV and also in abbreviated form in Table 3.1.

B. Phosphorus

Since phosphorus is so intimately involved with calcium in bone and tooth formation, it is easy to lose sight of its many other metabolic involvements. Phosphorus is a component of phospholipids, which influence cell permeability and are components of the myelin sheathing of nerves. Many energy transfers in cells involve the high energy phosphate bonds in adenosine triphosphate (ATP).Phosphorus plays an important role in blood buffer systems; activation of several B-vitamins (thiamin, niacin, pyridoxine, riboflavin, biotin, and pantothenic acid) to form coenzymes requires their initial phosphorylation. Some typical phosphorus-related compounds are included.

1. Phospholipids

These are important compounds involved in the transport of fat materials in the body. They probably are intermediates in the utilization of fat which participate in the oxidation–reduction reactions involved in the release of energy.

2. Nucleoproteins

Nucleoproteins occur as components of cell nuclei. In nucleic acid, phosphorus is the form of phosphoric acid that is combined with a number of compounds including purines, pyrimidines, and carbohydrates. The nucleic acids not only play a role in cell activity as such, but also are involved in the enzymatic control of intermediate metabolism and tissue respiration. Nucleic acid cooperates with phosphorus combinations with three B-vitamins (thiamin, riboflavin, and niacin) in the metabolism of carbohydrates and the chemistry of muscular work and tissue respiration.

3. Phosphoric Acid Esters of Carbohydrates

Phosphoric acid esters are critical in the release of energy from carbohydrates. When glucose is converted to the storage form of glycogen, or when glucose is utilized for energy, phosphorus compounds are involved in these reactions. The breakdown of glucose and the release of energy is characterized by the oversimplified equation: glucose + adenosine triphosphate → glucose-6-phosphate + adenosine diphosphate + release of heat energy.

4. Riboflavin–Phosphate–Enzyme Complex

This complex is a part of the tissue respiration enzymes starting with "Warburg's yellow enzyme" and encompassing a number of such enzymes. This group functions not only to release energy for work, but also in maintaining muscle tone and resilience.

5. Diphosphothiamin

Also known as cocarboxylase, diphosphothiamin is active in the breakdown of carbohydrates through pyruvic acid and lactic acid stages.

6. Pyridoxal Phosphate

Also known as codecarboxylase, this enzyme is utilized especially in the removal of the COOH radical from amino acids which are destined to go through the energy release cycle rather than the protein building cycle.

Generalized phosphorus requirements for beef cattle are listed in Table 3.1, and requirements for more specific conditions are listed in the Appendix IV.

Phosphorus may be provided to beef cattle from a number of supplemental sources when the content of the diet of typical feedstuffs is inadequate. The

TABLE 3.3

Calcium and Phosphorus Content of Several Supplementary Sources[a]

Product	Calcium (%)	Phosphorus (%)
Steamed bonemeal	31.2	14.4
Dicalcium phosphate	22	18.5
Diammonium phosphate	0.5	20
Phosphoric acid, feed grade	—	23.5
Defluorinated rock phosphate	32	18
Limestone	34	—
Oyster shell	38	—

[a]National Research Council (1984).

availability of phosphorus to beef cattle from most sources is relatively high and so it is mostly a matter of economy in selecting which source to use. The one exception is the use of raw rock phosphate which contains toxic levels of fluorine, and thus should not be used. However, it is a common practice to remove practically all of the fluorine from raw rock phosphate by heating it to a very high temperature. Phosphorus and calcium contents of several sources of calcium and phosphorus are listed in Table 3.3.

Normal blood plasma phosphorus levels vary from 4 to 8 mg/100 ml. Erythrocytes contain much more phosphorus than the plasma; thus whole blood contains six to eight times as much phosphorus as does blood plasma.

Like calcium, phosphorus absorption is an active process. The amount of phosphorus absorbed is dependent upon source, intestinal pH, age of animal, and dietary level of calcium, iron, aluminum, manganese, potassium, magnesium, and fat (Irving, 1964). Excess phosphorus is excreted primarily in the feces.

Because many forages contain levels of phosphorus that do not meet the requirements of growing or lactating cattle (Black *et al.*, 1943), and because phosphorus-deficient soils are common, phosphorus deficiencies in cattle are widespread. Furthermore, mature forages and crop residues generally contain even lower levels of phosphorus, while cereal grains and oilseed meals contain moderate to high levels of phosphorus.

A deficiency of phosphorus results in decreased growth rates, inefficient feed utilization, and a depraved appetite (chewing of wood, soil, and bones, a condition called pica). Anestrus, low conception rate, and reduced milk production are frequently associated with phosphorus-deficient diets. Plasma phosphorus levels decline during a deficiency and such animals may have weak, fragile bones and become stiff in the joints. Excessive dietary phosphorus levels may cause bone

resorption, elevated plasma phosphorus levels, and urinary calculi as a result of precipitation of calcium and magnesium phosphates in the kidney.

In a review of availabilities to ruminants of phosphorus compounds, Peeler (1972) ranked availabilities of common sources of phosphorus in declining order, as follows: dicalcium phosphate, defluorinated phosphate and bone meal, and soft phosphate. Sodium phosphate and ammonium polyphosphate are approximately equal to dicalcium phosphate in phosphorus availability. Phytate phosphate is not well used by nonruminants, but ruminants appear to use considerable quantities of this form of phosphorus.

C. Sodium and Chloride

Sodium and chloride or salt have been recognized as necessary constituents of the diet of man and animals for centuries. The esteem with which salt is held may be exemplified by the fact that the word "salary" is derived from the latin word for salt. Salt in minimal quantities serves to enhance the palatability of foods and feed, while in larger quantities it limits food and feed intake.

The most common deficiency for salt can be seen in the "salt-seeking" behavior of animals. They will travel great lengths to satisfy their salt hunger. Confined cattle will lick at earth or wood, and especially at the bodies of other animals, in search of salt. If a marked salt deficiency persists, cattle will show signs of lack of thrift such as roughened hair coat and decline in body weight. Salt-deficient lactating cows will show a decline in milk production. All of these symptoms are rarely seen because salt is so easy to supply to cattle. Cattle should never be without salt; it should be supplied on a free choice basis at all times, if possible.

Sodium is present in the body primarily as the sodium ion, and its function appears to be independent of whatever ion it happens to be associated with, like bicarbonate, phosphate, or chloride. A major function of sodium is in the regulation of osmotic pressure within the body, or the pressure which affects the passage of water, nutrients, and waste material across membranes. Another obvious function of sodium is in the regulation of acid–base relationships within the body. The sodium ion is the chief cation of blood plasma, and this is true also for other extracellular fluids of the body. The sodium ion has an effect on irritable tissues, such as muscles. In fact, the rate at which the heart beats is regulated by the proportions of sodium, potassium, and calcium present.

Chloride functions as a part of gastric juice, in accompaniment with the hydrogen ion (hydrochloric acid). When gastric juice—and the hydrochloric acid accompanying it—is lost by vomiting, alkalosis may persist briefly due to a relative excess of bicarbonate, which had been neutralized by the HCl. Chloride is involved in regulation of osmotic pressure. The majority of the anions in the blood plasma and extracellular fluids are composed of chloride. Chloride is involved in the "chloride shift" which aids in regulation of the acid–base balance

of the blood. The chloride can exert its "base effect" in the blood plasma, thereby maintaining the desired acid–base relationship. When bases such as bicarbonate enter the blood, chloride can shift from the plasma into the blood cells, no longer exerting its base effect. In contrast, when the lungs remove bicarbonate from the blood, or when acid enters the blood stream, chloride shifts from the inactive state within the blood cells into the active state (base effect) by entering the blood stream.

Salt often is fed at elevated levels in feedlots where urinary calculi or "water belly" is a problem. Its function here is not understood but it may be that the additional salt causes increased consumption of water, and, subsequently, increased urination. Thus its role here may be merely flushing out the urinary calculi-predisposing materials.

Sodium is absorbed readily from the small intestine, apparently requiring no special conditions. However, a possible exception is that the excessive consumption of potassium results in excessive excretion of sodium, and vice versa. This apparent relationship might be due to poorer absorption of each when the other is present in excessive amounts. Since forages are especially rich in potassium, it is assumed that ruminants have a relatively greater sodium requirement than nonruminants. Sodium can be absorbed to a limited extent from the stomach; chloride, on the other hand, is absorbed primarily from the intestine.

Practically all of the excreted sodium chloride exits via the urine and tends to reflect ingested levels. Hagsten and Perry (1975) demonstrated that lambs excrete large quantities of salt in the urine when large quantities are consumed, but on markedly salt-deficient diets the excretion of salt is extremely low. The same researchers showed that plasma levels of sodium remained quite constant (33 ppm) over an 11 week period in which extremely low levels of sodium were being fed (0.01% of the dry matter). This indicates that the role of sodium in the blood is so critical that it is maintained at a constant level, when possible. However, the potassium level of the plasma declined 23% (211 to 170 ppm) over the same period. Apparently the adrenal gland produces a hormone, other than adrenaline, which regulates sodium levels in the blood, because animals suffering from Addison's disease excrete increased quantities of sodium in the urine. (Addison's disease is a disease of the adrenal glands and affects the physiology of the adrenal cortex, which, in turn, apparently regulates sodium metabolism.)

Hagsten *et al.* (1975) established the supplemental salt requirements of growing and finishing lambs at 0.20% of the "air-dry" diet, when it was shown that most diets contain 0.20% salt, to give a total requirement of 0.40%. These recommendations should be quite applicable to beef cattle. Thus, a minimum level of 0.20–0.25% supplemental salt for beef cattle is adequate.

Because cattle avoid consuming excessive levels of salt, it can be used to regulate intake by cattle of relatively more palatable feedstuffs. For example, the incorporation of salt into free choice protein supplements for beef cows grazing

low-quality roughages has been practiced for decades; the incorporation of 5% of salt in free-choice ground shelled corn fed on pasture caused a 22% decrease in corn consumption (18.4 vs 14.3 lb/head/day) (8.36 vs 6.50 kg) for cattle averaging 835 lb (380 kg) over a 195-day grazing period (Perry *et al.*, 1976b).

D. Potassium

Potassium often is classified in the "trace mineral elements" section when discussing mineral requirements for beef cattle. Perhaps this is due to the fact that, as herbivores, cattle consume large quantities of potassium in the roughage portion of their diet and thus quite often require little or no supplemental potassium. However, it should be borne in mind that cattle have a need for greater quantities of potassium than for any other mineral element. Table 4 of the 1984 NRC bulletin on Nutrient Needs of Beef Cattle lists the potassium requirement of beef cattle at 0.65%, with a range of from 0.50 to 0.70%; this is considerably higher than almost any beef cattle requirement for calcium, phosphorus, or salt. In contrast, potassium is only the third most abundant mineral element in the body, behind calcium and phosphorus. Why then is potassium required in greater quantities than either calcium or phosphorus? The probable explanation for this is that calcium and phosphorus are stored in greater quantities in the body than potassium, and thus there is greater turnover for potassium (Perry, 1994).

Potassium is the mineral constituent within the cell most involved with the regulation of osmotic pressure and acid–base balance. The potassium content of the erythrocytes (red blood cells) is 20 times greater than that of the plasma, whereas sodium is found primarily in the plasma, outside the cells. Red blood cells are permeable to water, thus water moves from the plasma to the red cells as the blood changes from arterial to venous circulation, and in the reverse direction as the blood reenters the arteries in the pulmonary circulation.

Potassium constitutes over one-half the cations in saliva; in milk it constitutes 28% of the total cations. It is used in enzyme reactions involving phosphorylation of creatine and facilitates uptake of neutral amino acids by the cells.

The adult bovine body contains 1 kg (2.2 lb) of potassium, of which 73% is found in the muscles. Potassium is associated with nitrogen metabolism.

The irritability of the nervous system is dependent upon a balance among calcium, potassium, and sodium ions. Thus a decrease in calcium ions increases irritability; an increase in potassium ions will cause the same effect.

It is unusual to detect "deficiency symptoms" for potassium since grasses and other forages are excellent sources of potassium. However, cattle finishing diets are composed largely of corn and/or other grains. The potassium content of many feed grains may not be more than 0.6%, whereas the potassium requirement for such animals is at least 0.7%. Such a potassium-borderline diet can cause finishing cattle to gain no more than 85 to 90% of their potential weight gain (Devlin *et al.*, 1969, Table 3.4).

TABLE 3.4

Effects of Dietary Potassium upon Weight Gains, Feed Consumption, and Serum Electrolytes in Steers[a]

	Level of dietary potassium (%)			
	0.36	0.50	0.67	0.77
No. of steers	6	6	6	6
Initial weight				
lb	744	721	729	751
kg	338	328	331	341
Final weight				
lb	676	796	870	903
kg	307	362	395	411
Daily gain				
lb	−0.64[A]	0.73[B]	1.39[C]	1.45[C]
kg	−0.29	0.33	0.61	0.66
Daily feed				
lb	7.9	13.2	16.3	16.9
kg	3.6	6.0	7.4	7.7
Feed/unit gain	—	18.3	12.1	11.6
Serum K (mEq/liter)	4.3[a]	5.4[b]	5.6[b]	5.3[b]
Serum Na (mEq/liter)	138[a]	139[a]	143[b]	143[b]
Rumen fluid pH	7.0	7.3	7.5	7.4

Note. Treatment means with differing superscripts differ A, B, C: $p < 0.01$; a,b,c, $p < 0.05$.

[a]Devlin *et al.* (1969). 105-day experiment.

III. TRACE MINERAL ELEMENTS

Several trace mineral elements are required for beef cattle (Table 3.5). Normally, natural feedstuffs meet most of the trace mineral requirements, but under some conditions this may not be the case. Furthermore, as the virgin deposits of certain trace elements in the soil tend to become depleted, more frequent occurrences of deficiency symptoms of several trace mineral elements have appeared.

A. Iodine

The only known physiological function of iodine is through the function of thyroxine, of which iodine is a part. Ingested iodine is transported rapidly to the thyroid gland, where it is incorporated into thyroxine as protein-bound iodine. The broad function of thyroxine is that of controlling rate of metabolism of the body. Thus, a decreased level of thyroxine results in a lower metabolic rate;

TABLE 3.5

Trace Mineral Requirements for Beef Cattle[a]

Element[b]	Growing	Finishing	Lactation	Maintenance
Chlorine (%)	—	—	—	—
Sodium (%)	0.08	0.08	0.08	0.08
Potassium (%)	0.65	0.70	0.40	0.40
Sulfur (%)	0.1	0.1	0.1	0.1
Magnesium (%)	0.1	0.1	0.1	0.1
Iron (ppm)	50	50	50	50
Zinc (ppm)	30	30	30	30
Manganese (ppm)	40	40	40	40
Copper (ppm)	8	8	8	8
Cobalt (ppm)	0.1	0.1	0.1	0.1
Iodine (ppm)	0.5	0.5	0.5	0.5
Molybdenum (ppm)	0.1	0.1	0.1	0.1
Selenium (ppm)	0.1	0.1	0.2	0.2
Fluorine—no requirements have been established for fluorine				

[a]National Research Council (1984).
[b]Expressed as units per unit of dry matter.

conversely, excess thyroxine results in increased metabolic rate. In addition to its effect on metabolism, thyroxine affects other processes such as differentiation of cells, body growth, and tonus of the muscles. When a deficiency of iodine (and thus of thyroxine) exists, the thyroid gland enlarges greatly in an apparent attempt to compensate for lowered thyroxine production. The enlarged thyroid condition is known as "big neck" or goiter in animals whose thyroid gland is outside the chest cavity, thus becoming quite apparent in the intact animal (cattle and sheep). Iodine deficiency can be anticipated when feedstuffs grown inland, away from the ocean, are fed; crops grown near the ocean generally contain adequate iodine.

There really is no excuse for an iodine deficiency in cattle today since iodine is provided so readily in stabilized iodized (0.007% of stabilized iodine) stock salt.

Iodine requirements for a 1100-lb (500-kg) cow have been estimated to be about 1 mg per day.

B. Magnesium

Magnesium deficiency symptoms rarely are encountered in beef cattle. However, it appears that the incidence of "grass tetany" or "blind staggers" is increasing, perhaps reflecting a depletion of the earth's natural store of the element. A magnesium deficiency, then, is characterized by hyperirritability, tetany, and

convulsions. In its final stages before death, cattle so affected thrash about with uncontrolled muscular spasms. Lowered blood magnesium is apparently the underlying cause. Grass tetany can be considered a magnesium-deficient disease, in the strictest sense. It may be a relative deficiency disease since a lowering of bone levels of magnesium cannot be demonstrated.

A high percentage of cases of grass tetany occur in the spring when grass is young and lush. It has been postulated that the availability of magnesium is decreased greatly in the springtime, possibly due to some blocking mechanism such as the presence of increased levels of soluble aluminum or the accumulation of ammonium ions.

Physiologically, markedly increased magnesium levels have a tranquilizing effect. Sleeping, hibernating animals maintain a much higher serum level of magnesium than active animals; the serum magnesium content of nonhibernating animals can be increased by artificially lowering body temperature. The intravenous injection of magnesium results in muscular paralysis similar to that following an injection of curare. Systemic magnesium in excess, then, depresses the central nervous system, while a deficiency results in the opposite effect.

Approximately 65% of total body magnesium is contained in the bones; one-third of magnesium in bone is combined with phosphorus, and the remainder is adsorbed loosely on the surface of the mineral structure. The remaining, nonbone magnesium is distributed among various tissues and organs. Normal plasma magnesium levels range from 1.8 to 2.0 mg/100 ml, with values below 1.0 to 1.2 mg/100 ml indicative of magnesium deficiency; an animal with levels this low should be afflicted with grass tetany.

C. Cobalt

Cobalt requirement of beef cattle is approximately 0.1 ppm of the dry matter. The cobalt requirement of cattle is actually a cobalt requirement for the rumen microorganisms for the synthesis of vitamin B_{12}. In other words, a cobalt requirement per se has not been identified; rather it is a B_{12} requirement of which cobalt is an integral part. Vitamin B_{12} (cobalamin) is of key importance in the utilization of propionic acid. Vitamin B_{12} is essential for the recycling of homocysteine after the loss of its labile methyl group.

Cobalt-deficient soils occur in many parts of the world, with large deficient areas in Australia, New Zealand, and along the southeast Atlantic coast of the United States. If cattle are confined to cobalt-deficient pastures or diets, they may appear to be normal for several weeks or months, depending on age and degree of deficiency. As body stores of vitamin B_{12} are depleted, a gradual loss of appetite and body weight occurs, followed by extreme anorexia, muscular wasting, and severe anemia, culminating in death. In severe deficiencies the mucous membranes become blanched, the skin turns pale, a fatty liver develops, and the body becomes almost totally devoid of fat.

D. Copper

Copper requirement of beef cattle is met with 4 ppm of copper in the dietary dry matter, when the diet is not excessively high in molybdenum and sulfate. In areas where the soil molybdenum and sulfate are high, the copper requirement may need to be increased two- to threefold.

Copper is necessary for hemoglobin formation, iron absorption from the small intestine, and iron mobilization from tissue stores. Ceruloplasmin, which is synthesized by the liver and contains copper, is necessary for the oxidation of iron, permitting it to bind with the iron transport protein, transferrin. Other enzymes which contain copper include lysyl oxidase, cytochrome oxidase, uricase, tyrosinase, glutathione oxidase, butyryl coenzyme A, and many more.

Most feedstuffs supply adequate copper, and reflect the copper content of the soil on which they were grown. For example, the soils of parts of Florida and of the Coastal Plain region of the southeastern United States are quite low in copper, and produce feedstuffs which reflect that deficiency. A copper deficiency may occur in calves fed milk diets for long periods of time, or in older animals subsisting on forage produced on copper-deficient soil. The signs of a copper deficiency in cattle include a depraved appetite, loss of condition, stunted growth, rough hair coat, anemia, diarrhea, depigmentation of the hair, and sudden death.

E. Manganese

Manganese requirement for beef cattle is low, in the range of 10 to 20 ppm of the dietary dry matter. Although manganese is a dietary essential for beef cattle, most feedstuffs are adequate and thus a deficiency is relatively rare. Manganese deficiency in cattle, should it occur with marked severity, is characterized by reproductive disorders, including delayed estrus, reduced fertility, abortions, and deformed young. Calves born to manganese-deficient cows exhibit deformed legs (enlarged joints, stiffness, twisted legs, "overknuckling"), weakened shortened bones, and poor growth.

F. Zinc

Zinc requirements of beef cattle appear to be about 30 ppm of the diet dry matter. Zinc has a wide variance between required and toxic levels, with the latter being at about 900 ppm. Requirements are based on its biochemical function as both an activator and a constituent of several dehydrogenases, peptidases, and phosphatases that are involved in nucleic acid metabolism, protein synthesis, and carbohydrate metabolism.

A severe zinc deficiency results in rough, scaly skin, which itches and causes

much discomfort. The nose and mouth become inflamed and submucosal hemorrhage occurs. The animal develops an unthrifty appearance, roughened hair coat, and stiffness of joints. Finishing cattle show lowered weight gains in less severe deficiencies.

G. Sulfur

Sulfur is a component of protein, some vitamins, and several important hormones. Common amino acids that contain sulfur include methionine, cystine, and cysteine. Methionine is a key amino acid since all other sulfur compounds, except the B-vitamins thiamin and biotin, which are essential in normal body functions, can be synthesized from methionine. Body functions that involve sulfur compounds include protein synthesis and metabolism, fat and carbohydrate metabolism, blood clotting, endocrine function, and intra- and extracellular fluid and acid–base balance.

The ruminal microbial population has the ability to convert inorganic sulfur into organic sulfur that can be utilized by the host animal (National Research Council, 1984). Most diets fed to cattle contain adequate amounts of sulfur to meet the animal's needs. However, Meiske *et al.* (1966) demonstrated a sulfur response in cattle fed a high grain diet supplemented with nonprotein nitrogen. At one time there was a token patent for the feeding of urea nitrogen and inorganic sulfur in a 15:1 ratio for cattle. Rees *et al.* (1974) fed cattle pangola grass and caused an increase in dry matter intake and digestibility when the grass was either fertilized or supplemented with sulfur.

Requirements of beef cattle for sulfur are not well defined. Research covering this subject is very scarce, at best. However, there is an interesting relationship among copper, molybdenum, and sulfur which is noteworthy. Copper requirements are increased by the presence of both sulfur and molybdenum. As an example, copper forms cupric sulfide, an insoluble compound, rendering both unavailable to the animal; cupric molybdate also may be formed.

IV. ESSENTIAL TOXIC MINERAL ELEMENTS

This discussion is separated from the discussions for the other mineral elements because both fluorine and selenium were recognized for their toxic aspects before their beneficial aspects were recognized. The range between toxicity and nutritional benefit for both of these mineral elements is so narrow that both assume the role of "good guys" and "bad guys" in almost the same breath. In fact, the potential for toxicity of selenium is so great that levels permitted in livestock diets are regulated by the U.S. Food and Drug Administration.

A. Selenium

Selenium is similar to sulfur in its chemical properties. In 1973, glutathione peroxidase was shown to be a seleno enzyme (Rotruck *et al.*, 1973). It is proposed that glutathione peroxidase prevents membrane damage because of its antioxidant property. Any postulate concerning the biochemical role of selenium must also consider the interrelationship between selenium and vitamin E (Hoekstra, 1973). It has been demonstrated that selenium cannot be replaced completely by vitamin E, but that their functions intertwine to account for their partial replacement capability for each other.

In ruminants, a syndrome known as "white muscle disease" characterizes a selenium deficiency. It is characterized by white muscle striations, lameness, and heart failure. It is a muscular dystrophy that cannot be produced in calves on vitamin E-free diets unless such diets are high in unsaturated fats. It is postulated that depression of glutathione peroxidase in selenium-deficient animals may account for many of the manifestations of selenium deficiency.

Selenium was identified as a toxic substance nearly a third of a century before its essentiality was shown (Franke, 1934). General signs of toxicity include loss of appetite, loss of tail, sloughing of hoofs, and eventual death. Such death is the result of respiratory failure along with starvation and thirst. Two types of selenium poisoning have been observed, namely, acute or "blind staggers," and chronic or "alkali disease." Some edible herbages in seleniferous areas may contain as much as 5 to 20 ppm of selenium. This can be contrasted with the fact that the selenium requirement for beef cattle has been suggested to be 0.10 ppm (0.05 to 0.10 mg/kg) of dietary dry matter.

Feedstuffs reflect the soil levels of selenium on which they were grown. Therefore, "across-the-board" recommendations for the inclusion of selenium in cattle diets—especially for feedstuffs grown near seleniferous areas—are difficult to make. For example, within the boundaries of the state of South Dakota, there are selenium-toxic areas and also selenium-deficient areas!

Four techniques have been utilized in supplying supplemental selenium to beef cattle: (1) administering selenium as a drench, (2) subcutaneous or intramuscular injection, (3) placing selenium in fertilizers applied to pasture, and (4) using selenium as a feed additive.

B. Fluorine

Although fluoride is utilized in many municipal water systems for the protection of human teeth, specific evidence is lacking to identify any specific beneficial role for beef cattle. Conceivably, fluoride may have a beneficial effect for cattle teeth, but that remains to be seen.

Research with fluorine has been concerned primarily with the toxic aspect of fluorides in cattle, specifically the destructive effect on teeth and bone structure

Fig. 3.1 Tooth mottling typical of fluorine toxicity.

(Fig. 3.1). Certain rock phosphates must be defluorinated to make them safe for cattle feeding. Raw rock phosphate often contains 3.5–4.0% fluoride, which is toxic when such rock phosphate constitutes 1% of cattle diets.

The harmful effect of fluoride over prolonged periods of consumption is due to fluoride accumulation in the tissues; the bones become thickened and soft and their breaking strength decreases. Teeth may erode and the enamel may become mottled. Appetite decreases and depressed growth ensues. Fluoride is a cumulative poison and the toxic effect may not be noticed for some time. Because of this, maximum care should be exercised with breeding animals to be retained in the herd. Safe levels are no more than 100 ppm of fluoride in the diet of finishing cattle and no more than 40 ppm in the diet of cattle to be kept in the breeding herd.

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4

Protein Requirements of Beef Cattle

Michael J. Cecava

I. INTRODUCTION

Protein allowances for various feeding situations for beef cattle are listed in Appendix IV and represent a modification of those presented by the National Research Council (1984). The allowances are expressed on the basis of total protein either as a percentage of the dietary dry matter or as an absolute amount. Allowances can be exceeded without toxicity by feeding protein from natural sources, but excessive levels of nonprotein nitrogen (e.g., urea) are highly undesirable because of stress on the liver and kidneys and the possibility of ammonia toxicity.

The calculation of protein allowances is based upon the sum of three functions which require protein: (a) maintenance, (b) unavoidable losses of protein in the feces, and (c) production. Maintenance protein accounts for cutaneous (skin, hair) and endogenous urinary protein needs. The loss of protein in the feces is considered a function of indigestible dry matter intake and accounts for sloughing of intestinal tissues and the formation of indigestible proteins by the gut microbes. Production needs account for lean tissue accretion and are a function of rate of gain at a given live weight. Protein gain in conceptus and for milk protein synthesis also is considered for reproducing females. Composition of gain varies from 18% protein for steers weighing 220 lb to 9% for steers weighing 1100 lb. Corresponding values for heifers vary from 18 to 7%. Protein requirements for dry pregnant cows and for nursing cows calculated as above tend to be relatively high. For mature animals, unavoidable fecal protein losses account for the largest proportion of total protein need, whereas for growing animals lean tissue synthesis is quantitatively most important.

II. AMINO ACIDS

The proteins are a very complex group of compounds that contain carbon, hydrogen, oxygen, nitrogen, and, in some cases, sulfur. Hydrolysis of protein

produces free amino acids. An amino acid is an organic acid which contains an NH_2^- group. For example, the structure of propionic acid, commonly used as a preservative for high moisture grains, is:

CH2—CH2—COOH
propionic acid.

With the addition of an amine group at the α-carbon, the compound now becomes the amino acid alanine (α-aminopropionic acid):

```
CH2—CH—COOH
     |
    NH2
```

alanine.

There are many types and kinds of amino acids. Most nutritionists agree there are 23 amino acids constituting the proteins of animal nutrition. Of that number, approximately 10 or 11 are "essential amino acids," which by definition cannot be synthesized by the animal in sufficient quantities.

There is a growing body of evidence suggesting that ruminants require specific quantities of essential amino acids for optimum growth and lactation. Therefore, protein supplementation of beef cattle diets is gravitating toward strategies similar to those used for swine and poultry. This is especially true for young beef cattle, whose requirements for protein are quite high. Optimizing the supply of amino acids to the growing or lactating ruminant improves efficiency of protein utilization and, in many cases, improves feed (energy) intake. Consequently, protein supplementation strategies for growing and finishing beef cattle are discussed later in this chapter.

III. THE ROLE OF PROTEIN

The name "protein" was suggested many years ago because of its basic role in protoplasmic materials and refers to a product of primary importance. It would be most difficult to pinpoint specific functions of proteins and amino acids because almost every organ/system in the body utilizes proteins or amino acids. In addition to its obvious role as a part of "protoplasm," protein is a constituent of hormones and enzymes; it constitutes a large proportion of the dry weight of muscle, skin, blood, and body secretions. Protein and amino acids play such a prominent role in animal physiology that it is reasonable to say protein is "basic" to life.

IV. PROTEIN DIGESTION

Protein digestibility in the ruminant prior to entry into the small intestine differs greatly from that in the monogastric animal. Variable amounts of ingested

protein pass from the rumen intact, but for most feeds a substantial proportion of protein is degraded by ruminal microorganisms to peptides and amino acids. Some of the peptides and amino acids may pass to the small intestine, where they are absorbed. However, the majority of amino acids are deaminated in the rumen to form free ammonia plus the carbon skeleton from which the ammonia was removed. Ammonia is incorporated into amino acids by the ruminal microbes and eventually microbial protein is formed. About 50 to 80% of microbial nitrogen is derived from ammonia with the remaining proportions being derived from peptides and amino acids that are directly incorporated into microbial protein. A second fate of ammonia may be absorption across the wall of the rumen into the bloodstream. Absorbed ammonia is transported to the liver where it is synthesized into urea. Urea may then (1) go to the kidneys for excretion in the urine, (2) pass into saliva and then back into the rumen, or (3) pass into the bloodstream and back to the gut. Urea which enters the rumen either through recycling or from dietary sources is deaminated and metabolized as described above.

The extent of dietary protein breakdown in the rumen is affected primarily by the rate of protein degradation and the rate of passage of digesta from the rumen. Degradation rate is influenced by physical and chemical properties of a protein, such as tertiary structure and solubility. Most proteins contain at least three subfractions that biologically have been defined to have the following properties in the rumen: (1) fraction A—rapidly and completely degraded in the rumen, (2) fraction B—protein that is potentially degradable in the rumen, and (3) fraction C—indigestible protein. Subfraction B is proportionally the largest fraction found in most feedstuffs and the rate of degradation and passage of this fraction most affects ruminal degradability of a particular feed protein. Sniffen *et al.* (1992) offers an excellent discussion of our current understanding of ruminal protein degradability.

Protein that is presented to the small intestine is the sum of microbial protein synthesized in the rumen, dietary protein which escapes ruminal breakdown, and endogenous secretions. Through hydrolytic and enzymatic processes occurring in the abomasum and upper small intestine, amino acids and peptides are made available for absorption. True absorption of amino acids of dietary and microbial origin lies somewhere between 80 and 90%, although overprocessing (e.g., overheating) can reduce digestibility.

The fate of absorbed amino acids may be twofold. A primary requirement is for the resynthesis of tissue protein and other nitrogen-containing constituents, such as enzymes, hormones, and milk. Theoretically, formation of tissue protein is the reversal of the hydrolysis observed in the digestion process. Blood plasma proteins are primarily manufactured in the liver.

A second fate of absorbed amino acids is that of deamination. Both the kidneys and the liver deaminate amino acids. The enzyme involved is amino acid oxidase, which is involved in the formation of a keto acid plus free ammonia.

Keto acids can be (1) converted to fat, (2) converted to carbohydrate, (3) resynthesized into an amino acid, or (4) oxidized to carbon dioxide and water.

The liver represents the primary site of amino acid deamination and urea formation through an active "urea cycle." In the urea cycle, ornithine combines with carbamylphosphate (an ammonia-phosphorylated carbon complex) to form citrulline, which is converted to argininosuccinate; this is split into fumarate, which leaves the cycle, and arginine. Arginine is hydrolyzed to form ornithine and urea, with the latter being excreted in the urine. Ornithine then reenters the cycle. The urea cycle is an energy-consuming process and detoxification of ammonia arising from excessive protein feeding can require up to 2 Mcal of energy/day. This significantly reduces the availability of energy for growth and productive functions.

Ingestion of all nutrients elevates the metabolic rate, but ingestion of protein has a more pronounced effect than that for carbohydrates or fats. This tendency to increase the release of energy (and increase metabolic rate) is called heat increment. Ingested amino acids are not stored to any great extent. Therefore, ingestion of relatively large quantities of amino acids may temporarily overwhelm the needs of the tissues for amino acids, thus increasing the rate of deamination and subsequent oxidation. This effect plus the formation of urea in the liver, and its excretion by the kidneys, probably accounts for at least one-half of the heat increment attributed to protein ingestion. Heat increment should be taken into account in calculating a calorically adequate diet. This effect may account for as much as 6 to 10% of the total calories needed.

V. NONPROTEIN NITROGEN (NPN)

Characterized primarily as urea, NPN is a typical ingredient in diet formulation. Urea's place in cattle feeding is justified because ruminal microbes require a source of available nitrogen to synthesize microbial protein and because urea feeding makes economic sense. One pound of urea contains the crude protein equivalent of over 6 lb of soybean meal, and therefore the price advantage of urea as a source of protein for beef cattle is obvious.

Urea contains no available energy. Researchers recognized this and pointed out that when 1 lb of urea replaces slightly over 6 lb of an oil meal, on a crude protein basis, a loss of 6 lb of high-energy feed also occurred. Therefore, a more correct replacement value for urea is that 1 lb of urea *plus* 6 lb of corn, or other high-energy feedstuff, can replace 6 lb of soybean meal on an energy basis. On a protein basis, 5.2 lb of corn and 0.8 lb of urea provide an equal amount of protein as 6 lb of soybean meal at one-third the cost. Therefore, urea should be considered in supplement formulation, especially for finishing cattle fed concentrate diets and as a partial replacement for true protein in moderate energy grower diets.

Research has revealed a great deal concerning factors which assist the ruminal microbes in utilizing urea nitrogen more effectively. Naturally, it is critical that the diet contain a balance of nutrients in the appropriate form and sequence for optimum urea utilization. These factors are elaborated below.

Some natural protein is required for optimum performance, although cattle can survive if they receive all their protein from NPN. There is growing evidence that synthesis of protein by the ruminal microbes can be stimulated by feeding natural protein supplements, such as soybean meal. This appears to be especially true for high-concentrate diets. A good "rule of thumb" is that not more than one-third of total dietary protein should be derived from NPN. This is not a hard and fast rule; pregnant brood cows fed low-quality roughages often may derive two-thirds of their total protein from NPN and perform quite well.

Both basic and applied research have shown that the rumen microbes synthesize protein more efficiently when diets contain ruminally degradable true protein. Examples of degradable true protein include soybean meal, cottonseed meal, and sunflower meal. Improvements in nitrogen utilization when diets contain degradable true protein may be attributed to direct utilization of amino acids and peptides by ruminal microbes for protein synthesis. Also, the slower degradation rate of true protein compared with urea may coincide more closely with the release of energy from carbohydrate fermentation. Furthermore, end-products of true protein are essential growth factors for some species of ruminal microbes, especially cellulose fermenting species.

A source of readily available carbohydrate is essential for optimum utilization of NPN. Ruminally available carbohydrates, such as starch and degradable cell walls, provide energy needed by the rumen microbes for the synthesis of amino acids from ruminal ammonia and carbon skeletons. If carbohydrate is not available, ammonia is absorbed into the bloodstream and its effective use is greatly diminished. An excellent source of carbohydrates for use in manufacturing protein supplements containing higher levels of urea is cane molasses. This lends itself to manufacture of either liquid or dry formulations. Diets containing moderate to high levels of corn, milo, or barley also provide carbohydrate substrates for improved utilization of urea. In contrast, low-quality roughages do not provide a readily available source of carbohydrates. Therefore, it is necessary that the protein supplement fed in such a program should contain a source of rapidly available carbohydrate, for example, 10–15% molasses in dry supplements and up to 50% molasses in liquid supplements.

Numerous feedlot tests and university research have shown rather clearly that there is no significant difference between the nutritional value of liquid or dry high-urea beef cattle supplements when both contain the same balance of essential nutrients. Thus, for the cattle feeder it is a matter of choice between dry and liquid forms of protein supplement. Some of the advantages of liquid urea supplements are reduced labor, more uniform distribution of urea, and less variation in feed intake by cattle. Potential disadvantages are that specialized

mixing and feeding equipment are needed and that some nutrients are difficult to keep in suspension (e.g., calcium).

Urea can be added to corn silage during ensiling at the rate of 10 lb per ton of wet material. This will increase the crude protein content from about 8 to 12% and also will increase the lactic acid and acetic acid content of the silage. Ammonia also can be added to corn silage during ensiling at the rate of 7 lb of anhydrous ammonia per ton of wet silage. The effects on nutrient content are similar to that of urea addition. Adding urea or ammonia to corn silage has been shown to improve feed intake and milk production compared with feeding low protein silage/corn diets (Schingoethe and Beardsley, 1975). If corn silage with added urea or ammonia is the major source of protein in the diet, one should consider adding sulfur to ensure a nitrogen:sulfur ratio of 15:1 or less. Adding 1.8 lb of calcium sulfate (gypsum) during ensiling is a practical way of providing adequate sulfur for the ruminal microbes.

The nitrogen excretion product of poultry is uric acid. Therefore, poultry droppings offer a source of NPN for cattle feeding. Poultry manure from layer operations contains 25 to 35% crude protein whereas that from broiler operations has about 18 to 30% crude protein and more fiber, due to the presence of absorbent materials (e.g., sawdust). Layer waste contains about 75% moisture and dehydration to 15% moisture or less requires substantial energy inputs. Poultry manure is the most nutritious of all animal wastes so the costs of moisture removal are balanced by the nutritive value of the dried product. Growth and lactation of cattle fed poultry waste generally are slightly lower compared with the performance of control cattle but lower performance may be economically justified by increased profitability (NRC, 1983).

VI. PROTECTED OR SLOWLY DEGRADED PROTEIN

Feed proteins vary in their rumen solubility such that the rate and extent of ruminal degradation is quite variable. Protein which escapes ruminal degradation is classified as ruminally undegradable protein (RUP), or bypass protein. The RUP content of selected feeds is shown in Table 4.1 and an expanded list is presented in Appendix V. It should be recognized that RUP sources are not of equal quality with respect to essential amino acid content. Table 4.1 compares the essential amino acid content of protein sources with the amino acid pattern of milk protein. Milk protein is used as a reference because it is a high quality animal protein. Protein sources having a balanced amino acid pattern have higher essential amino acid indexes. Several points are apparent based upon the data presented. First, there is a large amount of variation associated with estimated RUP content of protein sources. In part, this variation is associated with methodologies used to measure ruminal escape but also may be a measure of the true

TABLE 4.1

Ruminal Escape (% of Total Protein) and Essential Amino Acid (EAA) Index of Protein Feeds[a]

Feed	Number of samples	Escape (%)	Standard deviation	EAA index[b]	Limiting amino acids		
Blood meal	2	82	1	60	Ile	Arg	Met
Meat meal	1	76	–	53	Ile	Trp	Leu
Feather meal	1	71	–	34	His	Lys	Met
Fish meal	26	60	16	68	Ile	Leu	Val
Dehydrated alfalfa	8	59	17	65	Lys	Ile	Arg
Corn gluten meal	3	55	8	52	Lys	Trp	Arg
Meat and bone meal	5	49	18	51	Trp	Ile	Leu
Brewer's grain	9	49	13	67	Lys	Arg	His
Distiller's grain with solubles	4	47	18	54	Lys	Ile	Arg
Soybean meal	39	35	12	71	Ile	Leu	Met

[a]Adapted from Chandler (1989).
[b]Calculated using milk protein as a standard. EAA index of ruminal microbes = 82.

variation in escape caused by feed processing and by the conditions under which the protein was fed. A second point is that no one protein provides an optimum pattern of amino acids relative to the pattern of milk protein. Fishmeal, brewers grains, and soybean meal are relatively high quality protein sources; unfortunately, soybean meal protein is extensively degraded in the rumen in most feeding situations. Some protein sources provide large quantities of protein postruminally but the protein has a relatively poor balance of amino acids. Feathermeal is a good example. A third point is that microbial protein has a better profile of amino acids compared with animal and vegetable proteins commonly used as supplements. Therefore, diets should be balanced to provide nutrients in the correct amounts and forms for maximal microbial protein synthesis. In most cases, this not only will improve protein status of the animal but will improve feed intake and energy status as well.

VII. EFFECTS OF PROTEIN SUPPLEMENTATION ON THE PERFORMANCE OF GROWING AND FINISHING CATTLE

Research studies involving high RUP supplements, such as corn gluten meal, dehydrated alfalfa, brewer's grains, distiller's grains, and blood meal, have shown that feeding bypass proteins in combination with urea improved growth rate or feed efficiency compared with feeding soybean meal or urea alone (Table 4.2). In cases where performance improved, essential amino acid flow to the

TABLE 4.2

Effects of Protein Source on Performance of Growing Cattle Fed Corn Silage and Corn-Based Diets

	Supplemental protein source					
	Urea	Soybean meal (SBM)	Blood meal (BM)	Corn gluten meal (CGM)	50 BM: 50 CGM	
Stock *et al.* (1981)						
Gain (kg/day)	0.64	0.70	0.75	0.75	0.78	
lb of feed:lb of gain (F:G)	9.2	8.6	8.1	8.4	7.8	
	Urea	SBM	BM	Meat and bone meal	Dehydrated alfalfa	
Loerch and Berger (1981)						
Gain (kg/day)	0.79	0.94	0.95	0.89	0.94	
F:G	7.6	6.8	6.7	7.0	7.1	
	Urea	SBM	50 SBM: 50 feather meal (Fth)	25 Urea: 75:Fth	50 Urea: 50 Fth	75 Urea: 25 Fth
Perry (1988)						
Gain (kg/day)	1.36	1.45	1.57	1.55	1.47	1.38
F:G	6.0	6.0	6.0	5.7	5.8	6.1
	Urea	75 SBM: 25 Fth	50 SBM: 50 Fth	25 SBM: 75 Fth		
Cecava and Hancock (1994)						
Gain (kg/day)	1.51	1.50	1.46	1.64		
F:G	6.8	6.7	7.0	6.4		

TABLE 4.3

Efficiency of Supplemental Protein Utilization by Growing Cattle[a]

Source	PER[b]
Soybean meal	100
Distillers dried grains	203
Distillers dried grains + soybean meal	113
Dehydrated alfalfa meal	226
Corn gluten meal	189
Dehydrated alfalfa meal + corn gluten meal	242

[a]Rock *et al.* (1979).

[b]Calculated by comparing cattle performance when fed test proteins compared with soybean meal relative to supplemental protein intake.

small intestine likely improved with increasing dietary RUP. Researchers at the Nebraska Experiment Station have developed an approach to evaluate the protein value of supplemental proteins relative to soybean meal (Table 4.3). Their research indicates that supplementing diets with bypass proteins compared with soybean meal enhanced the growth rate of cattle ostensibly by improving absorbable amino acid supply. It is important to note that in developing these concepts, cattle were fed low or moderate energy diets based upon roughages or forages (e.g., corn cobs). For high concentrate diets based upon corn, feeding high levels of bypass protein may actually reduce performance compared with feeding soybean meal (Table 4.4). Why might this occur? If a large proportion of dietary protein passes out of the rumen intact, ammonia nitrogen concentrations may be insufficient for optimal synthesis of microbial protein. This can especially be true for corn-based diets because corn protein is relatively resistant to ruminal degradation (RUP = 50 to 60% of total corn protein). Thus, it is important that some highly degradable source of nitrogen, such as urea, be fed in combination with slowly degradable proteins to meet the ammonia requirement of the ruminal microbes. Otherwise, nutrient digestion can be decreased greatly and animal performance may be impaired.

Supplementing diets with bypass proteins does not consistently improve amino acid flow to the small intestine or growth rate and feed efficiency. This may be due to reductions in microbial protein synthesis when diets contain high levels of RUP or to inaccuracies inherent in estimates of dietary RUP content. In some cases, protein is not the first limiting nutrient so increasing protein supply has minimal effects on growth rate. In general, positive responses to RUP occur when rapidly growing, immature ruminants are fed diets containing low to moderate levels of metabolizable energy.

TABLE 4.4

Effects of Protein Source on Performance of Growing Cattle Fed Corn-Based Diets[a]

	Protein Source[b]			
	Urea	Soybean meal	SoyPLUS[c]	50 Blood meal: 50 corn gluten meal
Number of steers	7	21	21	21
Initial wt (kg)	301	300	300	304
Final wt (kg)	562	589	571	571
Day 0 to 28				
Gain (kg/day)[d]	1.24[g]	1.83[e]	1.65[e,f]	1.55[f,g]
DM intake (kg/day)	7.12[f]	8.06[e]	7.91[e]	7.55[e,f]
Kg gain/100 kg feed	17.1[f]	22.5[e]	21.0[e]	20.6[e]
Day 0 to 70				
Gain (kg/day)	1.46[f]	1.68[e]	1.61[e]	1.44[f]
DM intake (kg/day)	7.60[f]	8.42[e]	8.33[e]	7.84[e,f]
Kg gain/100 kg feed	19.5	20.1	19.3	18.5
Day 0 to 175				
Gain (kg/day)	1.50[f]	1.66[e]	1.55[f]	1.54[f]
DM intake (kg/day)	8.46	8.82	8.70	8.43
Kg gain/100 kg feed	17.8	18.8	17.9	18.2

[a]Ludden (1994).

[b]Supplemental protein sources were fed during Days 0 to 70 on test in diets containing 73 to 81% cracked corn, 15% corn cobs, and supplement to equal 100% (DM basis). Proteins provided an average of 30% of total dietary protein (12.4% CP diets on a DM basis). From Days 71 to 175 steers were fed a 91% corn-based diet supplemented with urea (11.5% CP on a DM basis). Steers were individually fed during the trial.

[c]Estimated ruminal escape protein content approximately twice that of soybean meal.

[d]Means in the same row with different superscripts are different ($p < 0.05$).

VIII. PROTEIN AND AMINO ACID REQUIREMENTS OF BEEF CATTLE

Growing and finishing beef cattle require minimal levels of dietary protein, which are a function of live weight and rate of gain. Appendix IV gives protein allowances both in pounds per day and as a percentage of DM intake. Diets containing corn and corn silage probably require supplemental protein for optimal growth rate. Feeding leguminous roughage may reduce the need for supplemental protein.

Ruminants require a source of essential amino acids for maintenance and tissue deposition. The essential amino acids arriving at the small intestine are a function of microbial amino acid flow and undegraded dietary protein flow. Microbial protein generally accounts for 40 to 60% of total intestinal protein flow and, as noted earlier, the essential amino acid pattern of microbial protein is quite

balanced relative to animal requirements. The constancy in essential amino acid supply to the small intestine imposed by microbial protein flow creates conditions whereby no single amino acid clearly limits growth by cattle in most feeding situations.

There is a growing data base suggesting that a certain pattern of essential amino acids may be necessary for optimum growth rate or efficiency of protein utilization. However, dietary manipulations, such as selection of source and level of supplemental protein, appear to minimally impact the pattern of amino acids arriving at the small intestine (Fig. 4.1). The average profile of essential amino acids at the duodenum presented in the figure is a summary of seven research trials involving steers fed 31 different diets. The diets were based upon corn and corn silage; dietary protein content ranged from 11.5 to 18% CP and RUP content ranged from 4.5 to 9.5% of DM. Supplemental protein was provided by urea, soybean meal, specially processed soybean meal products with enhanced RUP content, corn gluten meal, and blood meal. Test proteins provided 30 to 40% of total dietary protein intake. Based upon these data, there appear to be

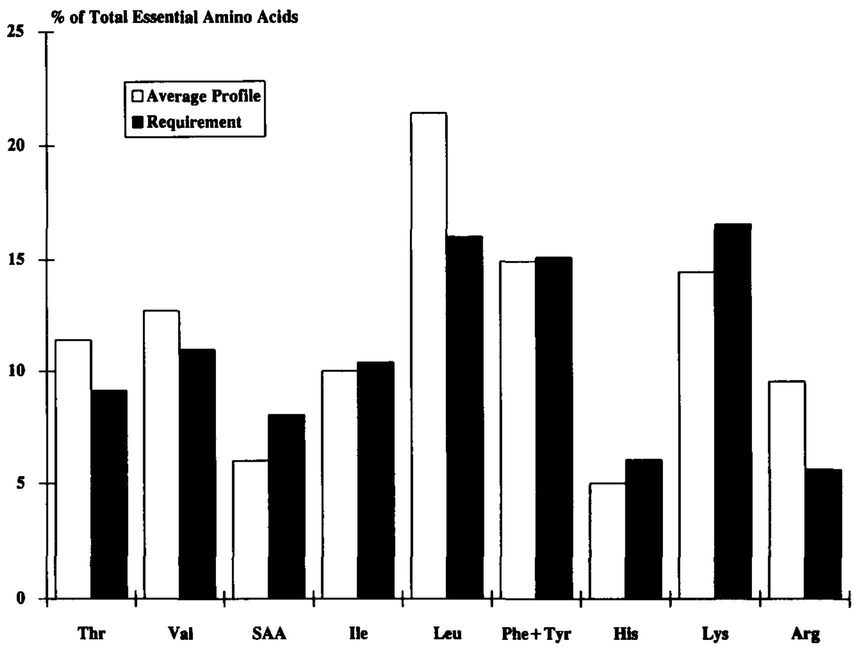

Fig. 4.1. Comparison of essential amino acid profiles of duodenal digesta and estimated essential amino acid requirements. Essential amino acid requirements adapted from Merchen and Titgemeyer (1992). Duodenal digesta profiles are the average of seven research trials conducted at the University of Illinois and Purdue University involving growing cattle fed 31 different diets. For a description of trials, see text.

only small effects of supplemental protein on the pattern of amino acids supplied to the animal. The most significant effect of supplemental protein is likely on the total quantity of amino acids supplied to the small intestine.

Based upon Fig. 4.1, it appears that increasing the proportions of lysine, sulfur amino acids, and histidine, and perhaps isoleucine, in duodenal digesta may create an essential amino acid profile that more closely meets the needs of the animal. Currently, crystalline lysine and methionine can be protected from degradation in the rumen through the use of encapsulation technology, and these products may be used to enhance flow of these amino acids to the small intestine. While the use of ruminally protected amino acids appears promising, the balance in duodenal amino acid supply suggests that two or more amino acids will be colimiting under most conditions. Consequently, providing a full complement of essential amino acids will likely result in greater animal response. This can be accomplished by providing adequate carbohydrate and protein for maximum microbial protein synthesis and by judicious use of supplemental true proteins having amino acid patterns in the RUP fraction that complement microbial protein.

IX. PROTEIN ADJUSTMENT DURING TEMPERATURE STRESS

Cattle feeders should be aware of how environment affects feed consumption and daily gain of cattle when formulating diets (Ames, 1979; Fox *et al.*, 1992). The most common environmental factor that alters nutrient requirements is temperature. Both heat and cold stress have a direct influence on the energy requirement for maintenance (Table 4.5) and DM intake (Table 4.6). Therefore, concentrations of other nutrients in the diet must be altered relative to energy concentration.

TABLE 4.5

Estimated Impact of Environment on Net Energy Requirements[a]

Scale value	Lot condition[b]	Multiplier for NE_m
1	Outside lot with frequent chill stress[c]	1.30
5	Outside lot, well mounded, bedding during adverse weather	1.10
7	No mud, shade, good ventilation, no chill stress	1.00

[a]Fox and Black (1984).

[b]Descriptions are associated with reduced external insulation resulting in varying degrees of chill stress. Adjustment for heat stress can be made by using scale value of 4 for deep, open-mouth panting and scale value of 6 for rapid, shallow breathing.

[c]Frequent mud combined with cold rain and/or wet snow, with no access to shelter or a dry place to lie down. Prolonged exposure to winds over 10 miles per hour during cold weather could have similar effects.

TABLE 4.6

Adjustment Factors for Effects of Temperature on Dry Matter Intake by Cattle[a]

Temperature (°F)	Multiplier
>95, no night cooling	0.65
>95, with night cooling	0.90
77 to 95	0.90
59 to 77	1.00
41 to 59	1.03
23 to 41	1.05
5 to 23	1.07
<5	1.16

[a]Adapted from Fox *et al.* (1992).

It is important to understand a number of terms which help describe this relationship. The first is "thermoneutral zone," which is the temperature at which heat production is offset by heat loss without the aid of special heat-conserving or heat-dissipating mechanisms. "Critical temperatures" are temperatures outside the range of the thermoneutral zone and growth or efficiency often declines for animals maintained under these conditions. Performance declines because feed intake often decreases or the animal must expend a greater proportion of total energy intake to maintain homeothermy (i.e., constant body temperature). Table 4.7 shows estimated critical temperatures for various coat conditions of beef cattle. Factors which are important include hair depth, hide thickness, tissue insulation (fat depth), wind speed and exposure to wet or muddy conditions (Fox *et al.*, 1992).

Environmental temperature affects growth rate and hence the need for protein (Table 4.8). At temperatures outside the thermoneutral zone, growth rate declines as does absorbable protein demand. For example, suppose a 900-lb steer having a "fall coat" of hair experiences an unseasonable warm spell of 75°F for 1 week.

TABLE 4.7

Estimated Critical Temperatures for Finishing Beef Cattle

Hair coat description	Critical temperature (°F)
Summer coat, or wet	59
Fall coat	45
Winter coat	32
Heavy winter coat	18

TABLE 4.8

Sample Ration Adjustment for a 900-lb Steer Exposed to Thermal Stress

	Deviation from critical temperatures (°F)	Decline in ADG[a] (%)	Protein for maintenance (g)	Protein for growth (g)	Protein in ration (g)	Crude protein in ration (%)
Hot	45	52.3	251.8	269.7	521.5	7.66
	40	39.1	251.8	344.3	596.1	8.75
	35	27.7	251.8	408.8	660.6	9.70
	30	18.2	251.8	462.5	714.3	10.49
	25	10.5	251.8	506.0	757.8	11.13
	20	4.8	251.8	530.3	790.1	11.60
	15	0.7	251.8	561.4	813.2	11.94
Critical temperature	10	—	251.8	565.4	817.2	12.0
	5	—	251.8	565.5	817.2	12.0
	0	—	251.8	565.4	817.2	12.0
Cold	5	2.3	251.8	552.4	804.2	11.81
	10	4.5	251.8	540.0	791.8	11.63
	15	6.8	251.8	527.0	778.8	11.44
	20	9.0	251.8	514.5	766.3	11.26
	25	11.3	251.8	501.5	753.3	11.06
	30	13.5	251.8	489.1	740.9	10.88
	35	15.8	251.8	476.1	727.9	10.69
	40	18.0	251.8	463.6	715.4	10.51
	45	20.3	251.8	450.6	702.4	10.31

[a]ADG, average daily gain.

The temperature is about 30°F above the thermoneutral zone, thus rate of gain will decline by about 18.2%. Protein content of the diet could be decreased from 12 to 10.49% (DM basis) and still provide adequate absorbable protein. Removing protein from the diet during thermal stress can improve protein efficiency with no penalty on performance. Furthermore, decreasing protein supplementation can reduce feed costs by several cents per day.

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5

Computer Programming of Beef Cattle Diets

Dale M. Forsyth

Computers have been useful in ration formulation for beef cattle for many years. Originally, computer formulation was carried out with main-frame computers that were very expensive and complicated to operate and were only available to large businesses and universities. Some universities made their computers accessible to the public so that more people could utilize computer formulation. Recently, however, with the advent of inexpensive powerful personal computers and user-friendly software programs, computers have become available to businesses of any size, including all those that deal with cattle.

Computers are especially useful in the area of least-cost programming (also called linear programming, because of the mathematical technique used), due to the complexity of procedures for solving the equations. Least cost rations have been especially important for large feedlot operators who purchase all feed ingredients and for feed companies that deal with many feedstuffs. Simpler programs that do not rely on price for determining the ration ingredients are also available and are useful for many situations. Spreadsheets, which are general purpose computer programs (such as Lotus 123, Quattro, or Excel) that relieve the user from much of the detail of developing computer code, also have been utilized for formulating livestock rations.

I. SOURCES OF RATION PROGRAMS FOR COMPUTERS

Ration balancing programs are available from commercial software companies and from universities for various kinds of applications and for use on everything from main-frame to personal computers. Recently, powerful spreadsheet programs for personal computers have made it easier for nutritionists to develop computer solutions without the need for as much programming expertise. Some of the spreadsheet programs, like Quattro-Pro and Excel, even have

built in optimization for calculating LP solutions, making least cost program development available to a wider audience.

II. LEAST-COST RATION ASSUMPTIONS AND PROBLEMS

Least-cost rations rely on the assumption that the same level of performance will be achieved if a minimum level of each required nutrient is met, regardless of the source of nutrients. For example, one assumes a pound of protein from cottonseed meal is equally effective as a pound of protein from soybean meal, or even urea. This assumption is not always correct. Urea as a source of nitrogen will not always provide for the same performance level as natural protein. Calories from fat are not always used in the same manner or with the same efficiency as calories from carbohydrate or protein.

Least-cost procedures are only mathematical methods for solving equations, and do not always produce the most practical rations to feed to livestock. A program may add, for example, a large amount of inappropriate feeds. Under certain conditions, it may be possible to include large amounts of limestone, salt, or another cheap feed as filler. Careful attention to restrictions can exclude most of the common problems of this sort. Both minimum and maximum restrictions on nutrient levels and specific feedstuff amounts can be used. Sometimes, however, restrictions are not included on feeds that ordinarily are not a major share of the diet. If wheat were cheap, it might be substituted for all the corn in a ration, but a nutritionist would recognize that while the feeding value of wheat is close to that of corn, practical diets would not be based on all wheat. Differences in palatability of feeds are not usually considered in the least-cost formulation, except as maximum restrictions of feedstuff inclusion levels. It is important that the results of least-cost formulated rations be inspected by someone knowledgeable about beef cattle nutrition to evaluate the practicality of the ration.

Another problem results if prices are not current and accurate. Since the decision function of which feedstuffs to use is based on price, it is of paramount importance that the prices used are correct. Similarly, the feedstuff composition for the feeds used must be accurate or the ration will not provide the nutrients at the correct levels. For example, the average value of protein in corn is near 8% but the range will be from 6.7 to 10.0%. Use of average values for feeds will lead to great amounts of inaccuracy in the ration.

Least-cost procedures do not usually have a mechanism for taking into account such complications as associative effects of feeds. Associative effects occur when the response to nutrients in a feedstuff are different in one ration than in another, depending on the feed ingredients in each ration.

Performance effects arising because of feed processing methods, even when

feeds contain the same level of nutrients, are known but not considered by typical least-cost programs. One way of taking this into account is to consider each processed feed a separate feedstuff, and to use composition values based on availability rather than total nutrient content.

Determination of the animal's requirements is difficult, given the variability of animals and all the things which influence requirement needs, but is not a problem only for least-cost rations. Estimation of voluntary feed intake, however, is important to ration formulation but difficult to achieve accurately in all conditions.

Another shortcoming of least-cost rations is that the ration calculated may not always be the most profitable one. Incorporating other information into the decision process is the goal of least-cost-of-production rations and of maximum-profit rations. These programs are not as commonly available, however.

III. NET ENERGY CONSIDERATIONS

Net energy concepts provide a more accurate description of energy use from feeds than TDN or digestible energy, and better predict performance of cattle based on energy intake. They are more complicated to handle in ration formulation, though, because each feed has different energy values for maintenance and for productive functions. The values are not independent; the energy needed for maintenance must be met before any additional energy is used for production, and that energy used for production will be used with a lower efficiency than for maintenance. Computer programs can make the necessary calculations. Simultaneous consideration of voluntary feed intake, however, presents another complication.

In the case of mature beef cows, the energy necessary to gain or lose weight depends on the current body condition of the cow, thin or fat. Equations for net energy needs in these circumstances are expected to be included in the next revision (1995) of the NRC Nutrient Requirements of Beef Cattle.

IV. SOLUTIONS FOR RATIONS

Balancing rations by any method requires: (1) knowing the requirements for nutrients of the animals to be fed, (2) knowing the composition of feedstuffs to be used with regard to those nutrients, and (3) a procedure for combining feeds to meet those requirements. The LP procedure allows many feeds to be considered for the ration, with selection of which feeds and in which amounts to be determined on the basis of feedstuff prices. Mathematically, where Feed_n represents

the quantity of the nth feedstuff, and NUT_n represents the concentration of the nth nutrient for which you are balancing, the linear equations are represented by

$$
\begin{aligned}
&\text{Feed}_1 + \text{Feed}_2 + \text{Feed}_3 \ldots + \text{Feed}_n && = 100 \\
&\text{Feed}_1(\text{NUT}_1) + \text{Feed}_2(\text{NUT}_1) + \text{Feed}_3(\text{NUT}_1) + \ldots + \text{Feed}_n(\text{NUT}_1) && > \text{NUT}_1 \\
&\text{Feed}_1(\text{NUT}_2) + \text{Feed}_2(\text{NUT}_2) + \text{Feed}_3(\text{NUT}_2) + \ldots + \text{Feed}_n(\text{NUT}_2) && > \text{NUT}_2 \\
&\text{Feed}_1(\text{NUT}_n) + \text{Feed}_2(\text{NUT}_n) + \text{Feed}_3(\text{NUT}_n) + \ldots + \text{Feed}_n(\text{NUT}_n) && > \text{NUT}_n
\end{aligned}
$$

In the representation above, all of the feedstuffs add up to the whole of the ration. Each feedstuff amount multiplied by its nutrient composition (NUT), for each nutrient, adds up to, or exceeds, the amount of that nutrient required in the ration. Typically the variable nutrients balanced for include protein, energy, calcium, phosphorus, and other nutrients that are individually considered. The restrictions can be made to be equal to, less than (<) or greater than (>) the given right hand side member (RHS), or requirement. Typically the nutrient composition of the feedstuffs and the RHS values are arranged in tables. The software package then combines the values according to the restrictions, calculates the solution to the equations, and presents the solution, displaying the ration cost, the feedstuff amounts, and often additional information. Other useful information includes penalty cost, which is the added cost of using a feedstuff that is not part of the solution, and shadow price, which is the incremental cost of increasing the value of a nutrient amount.

V. USE OF SPREADSHEET PROGRAMS

Spreadsheet programs have become very popular for keeping financial records, for doing what-if planning, and for making other calculations. Three of the most popular spreadsheet programs with which the reader might be familiar are Lotus 123, Quattro Pro, and Excel. These programs have become powerful tools that can be used with relatively less programming expertise than is required for the use of computer programming languages such as FORTRAN, Pascal, and Basic.

Templates have been developed for use with spreadsheet programs for checking and for balancing beef rations. Templates contain the words, instructions, and equations to provide the specific application to be used with the spreadsheet program. They have been especially useful to consultants for checking the adequacy of a client's ration, and for making adjustments to bring a ration into better balance.

Powerful spreadsheets have built-in procedures for matrix algebra calculations, and therefore can easily solve simultaneous equations. Considering a specific case of the generalized equations presented earlier, one can see that

solving for crude protein and TDN with hay, corn, and soybean meal (SBM) can be done directly and easily.

$$\begin{aligned} 100 &= \text{Corn} + \text{SBM} + \text{Hay} \\ \text{CP} &= \text{Corn}(\text{CP}_{\text{Corn}}) + \text{SBM}(\text{CP}_{\text{SBM}}) + \text{Hay}(\text{CP}_{\text{Hay}}) \\ \text{TDN} &= (\text{Corn})(\text{TDN}_{\text{Corn}}) + (\text{SBM})(\text{TDN}_{\text{SBM}}) + (\text{Hay})(\text{TDN}_{\text{Hay}}) \end{aligned}$$

Let the requirements be represented by matrix R. R is a matrix of n rows and 1 column, where n = the number of requirements. Let the feedstuffs analysis values be represented by matrix C. (C is a matrix of n rows and n columns, where n = the number of nutrients that also must equal the number of requirements). Let the feedstuff amounts, i.e., the answers, be represented by B. Then, in matrix notation, R = B C. Therefore: $B = C^{-1} R$. In other words, to get the amount of each feedstuff to feed, multiply the inverse (the matrix algebra equivalent of dividing) of C (the composition table) by R (the requirements). Use the matrix inversion procedure of the spreadsheet to obtain the C inverse and then use the matrix multiply procedure to obtain the answers.

There are precautions that must be noted. The solution can include negative feedstuff amounts when a nutrient is present at a higher level than needed. Therefore, it often does not work well for cattle rations containing alfalfa, which is high in protein. Expanding the procedure to more than two nutrients is easy but not often practical because, again, the likelihood of the correct solution containing negative numbers becomes too great. For example, if one includes calcium and phosphorus as nutrients for which to solve, alfalfa may contain more calcium than required and negative amounts of limestone will be the result.

VI. OTHER COMPUTERIZED METHODS

Least cost of production and maximum profit procedures have been mentioned previously. Nonlinear programming procedures have been described, to accommodate situations in which one-to-one relationships between feedstuff levels and responses do not exist. Stochastic programming procedures have been described for taking into account in a systematic way the uncertainty associated with requirements or the composition of feedstuffs. This procedure may be relatively more important for commercial feed mills where a minimum nutritional value must be guaranteed. Computer modeling programs are also in use in research, to explore relationships between the rumen, animal growth, and nutritional requirements.

6

The Effect of Processing on the Nutritive Value of Feedstuffs for Beef Cattle

Tilden Wayne Perry

During a two decade period (1960–1980) a great deal of research was conducted to determine the effect of various methods of processing on the nutritive value of feedstuffs for beef cattle. The National Academy of Sciences recognized the potential impact of the feed processing research which had been conducted and appointed a committee to prepare a review of such research (1973). Although some additional research on the effect of feed processing has been conducted since that time, such research has not made very great contributions to the subject. Prior to 1960 the major methods of feed processing for cattle consisted of the grinding of grains and the ensiling of certain hay crops and the whole corn plant. However, cattle feeders currently practice a wide variety of feed grain processing and roughage processing techniques.

I. PROCESSING OF FEED GRAINS

Several methods of grain processing have been developed. All but two of them require heat energy to complete the process—only grinding and moisturizing require no supplemental heat. Feed grain processing techniques in common practice today include extrusion, gelatinization, grinding, micronizing, moisturizing, popping, roasting, and steam flaking. Much of the discussion on grain processing—except for moisturizing—is derived from the National Academy of Sciences (1973) publication referred to above; the discussion on high-moisture grains is based on a review by Merrill (1971).

A. Extrusion

This is accomplished by forcing dry grain through an orifice, utilizing an augerlike rotor which crushes the grain prior to the time it reaches the orifice. The resulting ribbonlike strip from the orifice breaks into flakes of different

TABLE 6.1

The Comparative Value of Flaked Raw Corn, Extruded Corn, Milo, and Ensiled High-Moisture Corn for Beef Cattle[a]

Treatment	Daily gain lb	Daily gain kg	Daily feed lb	Daily feed kg	Feed/unit gain
Flaked corn	2.85	1.30	22.7	10.3	8.0
Extruded corn	2.69	1.22	23.0	10.4	8.6
Extruded milo	2.74	1.25	23.6	10.7	8.6
High-moisture corn	2.73	1.24	21.9	10.0	8.0

[a]Matsushima *et al.* (1969)

shapes and lengths. A great deal of the research on extrusion was conducted at Colorado State University.

In one experiment (Matsushima *et al.*, 1969) finishing steers were fed a diet containing processed grain, limited corn silage (19 lb/day, or 8.6 kg), 2.4 lb (1.1 kg) alfalfa hay, 1 lb (0.45 kg) beet pulp, and 0.71 lb (322 g) protein supplement. Cattle fed extruded grain gained more slowly and required more feed per unit gain than cattle fed flaked corn; those fed high-moisture corn gained similarly to those fed flaked corn (Table 6.1). In subsequent research, McLaren and Matsushima (1970) reported that cattle fed extruded grain at 85% concentration made gains comparable with those of cattle fed flaked corn (2.79 versus 2.76 lb/day;1.26 versus 1.25 kg/day). Efficiency of gain and carcass quality were comparable for the two groups.

Digestibility studies compared extruded grain with flaked grain (Matsushima, 1970). Both thin-flaking and dry extrusion improved digestibility of dry matter, crude fiber and crude protein over that of whole corn (Table 6.2). The wet-extrusion process was not as effective in improving digestion as was dry extrusion. Conceivably, the presence of moisture in the wet-extrusion process caused

TABLE 6.2

Flaking versus Extrusion of Corn: Effect on Cattle Digestibility[a]

Treatment	Digestibility (%) Dry matter	Digestibility (%) Crude protein	Digestibility (%) Crude fiber
Whole	65	41	17
Thin-flaked	74	55	23
Dry-extruded	71	52	21
Wet-extruded	68	48	20

[a]Matsushima (1970).

sufficient cooling that the usual cooking-heating associated with dry extrusion did not take place. Feedlot tests on the four types of corn showed comparable daily gains (2.97–3.17 lb/day; 1.35–1.44 kg/day), but feed efficiencies (unit of feed per unit of gain) showed interesting differences: whole corn, 7.6; thin flaked, 7.0; dry extruded, 7.1; wet extruded, 6.8.

B. Gelatinization

Gelatinization is accomplished by subjecting ground grain to heating with steam to soften the grain, followed by forcing the resultant product with an auger through cone-shaped holes in an expander head. Such holes are smaller where the material enters and gradually enlarge until the feed is expelled, which causes a release as the grain moves through the die. This causes expansion of the grain. This technique is employed in the manufacture of expanded pet foods. Mudd and Perry (1969) conducted three metabolism trials and one feeding experiment with corn in which the starch was 100% gelatinized. In two of the three metabolism studies, the substitution of gelatinized corn for raw corn as a major constituent of the diet resulted in a significant and linear depression in the digestibility of nutrients; in the feeding trial, gelatinized corn decreased both feed intake and cattle gains.

Nebraska researchers (Wilson and Woods, 1966) reported that substitution of 15, 30, or 45% gelatinized corn for raw corn tended to improve both gains and efficiency of feed conversion of cattle.

C. Grinding

Grinding of corn is undoubtedly the oldest processing technique applied to feedstuffs for cattle, especially for feed grains. More recent research has demonstrated that grinding does not improve the nutrient value of corn for beef cattle. However, there may be situations wherein grinding is almost a necessity in order to obtain a relatively homogeneous mixture of the ingredients.

It has been demonstrated that on extremely high corn diets, with little or no roughage present, it is a distinct advantage not to grind the corn kernels. At time of slaughter, cattle fed high corn diets in which the corn has not been ground have a lower incidence of rumen parakeratosis than do those whose corn was ground. One explanation is that the hard kernel and sharp tip cap of unground corn may serve in part for the "scratch" effect provided by roughages in less concentrated diets.

D. Micronizing

Micronizing consists of heating grain to 300°F (149°C) by gas-fired infrared generators. The term micronizing was coined to describe this dry heat treatment

since microwaves are emitted from the infrared burners during the process. Texas research (Schake *et al.*, 1970) utilized a field trial involving two lots of 100 steers each to evaluate micronized milo against steam-flaked milo. Feedlot gains favored steers fed micronized milo, but efficiency of feed conversion favored steam-flaked milo. However, the report indicated that micronizing was a more economical process than steam flaking.

E. Moisturizing

Moisturized or high-moisture grain is the processing technique which perhaps gave impetus to the whole area of grain processing. The earliest reported data on the feeding value of ensiled high-moisture grains was in 1958 (Beeson and Perry), in which it was reported that ensiled high-moisture ground ear corn had 12–15% greater feeding value per unit of dry matter, based on comparable rates of gain and decreased dry matter intake. Unfortunately, the corn ear picker has been replaced by the picker–sheller combine and thus ear corn rarely is available for ensiling.

The storage of high-moisture grains is dependent upon either anaerobic fermentation, as in ensiling, or the prevention of mold formation by the use of such materials as organic acids, e.g., propionic acid. The matter of choosing which technique to employ is a matter of which method fits best into a given system of feed storage and cattle feeding, plus which is more economical (Fig. 6.1).

One of the real advantages of the high-moisture grain system of cattle feeding is that the harvest may be initiated 2 to 3 weeks before normally possible for harvesting grain which is to be artificially dried and stored in bins—the exception being barley. An equally substantial advantage to such a program is that expensive artificial drying is not necessary. Perhaps the greatest drawback to the high-moisture storage system is that such grain cannot be sold in commercial channels once it has been stored as high-moisture grain. Acid-treated high-moisture grain may be dried to an acceptable moisture content and subsequently introduced into commercial trade.

Moisture level of high-moisture corn is important. Burroughs *et al.* (1971) summarized the data from 17 reports involving different moisture levels of corn stored in limited oxygen storage (as in ensiling). An average improved feeding value of 10% for high-moisture ear corn showed a low of +7% when the corn contained 23 to 32% moisture, and a high of +13% for moisture levels of 33–44% (there was one high level of 23% improvement for 44% moisture corn in the higher moisture group). The higher moisture levels in the corn may cause some harvesting problems, and thus a realistic optimum for high-moisture ear corn is 30 to 35% moisture.

From high-moisture shelled corn, the average improved feeding value of 6% was partitioned into +7% for moisture levels of 23–27% and +5% for 28–35%

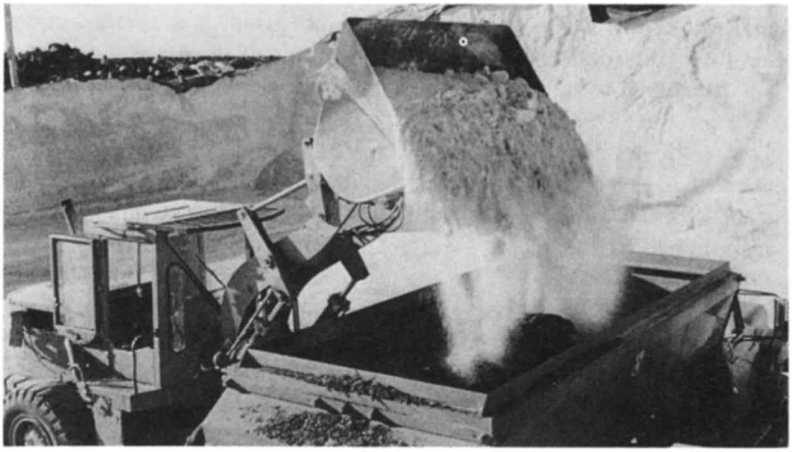

Fig. 6.1 Ensiled high-moisture corn is a most excellent cattle feedstuff. (Photo courtesy of BEEF Magazine.)

moisture levels. The recommended moisture level for high-moisture shelled corn ensiling is 25–30%.

The feeding results from "reconstituted" corn (dry corn treated with water to bring the moisture level to 25–30%) have been quite erratic. Generally, in the case of corn, it is recommended that original moisture high-moisture corn will give more consistent benefits than reconstituted high moisture corn.

Table 6.3 summarizes experiments in which high-moisture corn was compared with dry corn as cattle feed for beef cattle. From this summary, it is obvious that comparable gains were obtained from both types of corn, but cattle consumed an average of 6.9% less dry matter and thus required 6.7% less dry matter per unit of gain.

Embry (1971) presented data to show that rolled high-moisture shelled corn has a greater advantage over rolled dry corn when fed with corn silage than when fed in an all-concentrate diet. With corn silage, rolled high-moisture shelled corn produced equal or greater gains and had greater feed efficiency, whereas in all-concentrate diets, all comparative data were nearly the same for both types of corn. When hay represented about 65% of daily dry matter, high-moisture shelled corn resulted in 8% increased gain and 7% improved feed efficiency; with haylage at 65% of daily dry matter intake, rolled high-moisture shelled corn resulted in 12% faster gains and 10% less feed per unit gain than for dry rolled corn.

It has been concluded generally by research data on the subject that cattle respond to high-moisture shelled corn treated with organic acids as well as they respond to ensiled high-moisture shelled corn.

TABLE 6.3

Dry versus High-Moisture Harvested Corn Stored Whole[a]

	Dry-rolled corn			Ground-ensiled corn			
Station	Daily gain	Corn per day	Corn conv.[b]	Water content (%)	Daily gain	Corn per day	Corn conv.[b]
Illinois 1972							
lb	3.21	13.4	4.17	29.0	2.91	11.9	4.09
kg	1.4	6.1			1.3	5.4	
Iowa 1970							
lb	2.00	11.7	5.85	24.3	2.09	10.9	5.22
kg	0.9	5.3			1.0	5.0	
Iowa 1971							
lb	2.56	15.5	6.05	24.0	2.79	15.5	5.55
kg	1.2	7.0			1.3	7.0	
Iowa 1972							
lb	2.32	13.3	5.73	27.3	2.40	12.6	5.25
kg	1.1	6.0			1.1	5.7	
Michigan 1970							
lb	3.54	18.5	5.23	32.0	3.33	15.3	4.59
kg	1.6	8.4			1.5	7.0	
Minnesota 1971[c]							
lb	2.81	16.9	6.02	26.0	2.90	16.9	5.85
kg	1.3	7.7			1.3	7.7	
Minnesota 1971[c]							
lb	2.69	11.7	4.36	30.0	2.56	10.9	4.30
kg	1.2	5.3			1.2	5.0	
Average lb	2.73	14.4	5.34	27.5	2.71	13.4	4.98
Change (%)					0	−6.9	−6.7

[a]Data from Annual Beef Cattle Research Reports.
[b]Conv. = units of corn dry matter/unit of gain.
[c]Two different trials.

1. High-Moisture Sorghum Grain

Since milo is the basic energy grain of the sprawling cattle feeding industry of the Southwest, it is appropriate that Texas, Oklahoma and Kansas have conducted the majority of the research concerned with the nutritive value of high-moisture sorghum grains for beef cattle.

The benefits from high-moisture sorghum grain over comparable dry sorghum are more dramatic than those for corn. Their feeding value in the dry form is lower than their chemical composition would predict. Basic research into this discrepancy indicates that the starch of dry sorghum grain is less available and the protein is not utilized as well as that of dry corn or dry barley. Therefore, almost anything that can be done to sorghum grain probably will improve its nutritive value for cattle.

Cattle fed ground moist sorghum grain have required less grain dry matter per unit gain than those fed ground dry sorghum grain, ranging from 15 to 25% with an overall average of 20%. In practically all comparisons, high-moisture sorghum grains have resulted in lowered dry matter intake compared to other processing methods such as steam-flaked, ground, or rolled dry grain. With similar weight gains, then, feed efficiency favors utilization of high-moisture sorghum grain.

Further processing of high-moisture sorghum grain is important. For example, beef cattle fed ground high-moisture sorghum grain gained 11% faster and required 37% less grain dry matter per unit of gain than cattle fed the same high-moisture grain in whole form. Rolling either high-moisture grain sorghum or dry sorghum grain is superior to fine grinding for increasing efficiency of feed conversion.

Some investigators feel that the change that takes place in reconstituting grain sorghum is similar to that which occurs during germination in which the starch of the endosperm is liquified to an extent for use by the growing seedling.

The ideal average moisture content for high-moisture sorghum grain is 30% with a range of 25 to 35%. Similarly, the ideal reconstituted level is 30% moisture. However, it is most difficult to add more than 10 points of moisture above the starting point.

It is critical in the reconstituting of sorghum grain that the grain remain in the reconstituting-fermentation process for a minimum of approximately 21 days.

Increased dry matter digestibility has been proposed as the primary factor causing increased feed efficiency from using high-moisture sorghum grain. It has been shown, for example, that reconstituted high-moisture sorghum grain increases the digestibility of dry matter, organic matter, and nonprotein organic matter with a magnitude of 12 to 29%.

2. High-Moisture Barley

Barley kernels are physiologically mature when the moisture content drops below 40%. The ideal average moisture content for high-moisture barley is 30%, similar to that for high-moisture sorghum grain. All the physical advantages related to earlier harvesting for barley add to the increased feeding value of high-moisture barley. Research indicates that high-moisture barley has a place in cattle feeding—not because of increased gain, but because of improved efficiency of feed conversion. The chief advantage of high-moisture barley appears to be its high acceptability, with cattle "going on feed" more rapidly, resulting in better early gains. Cattle stay "on feed" easier on high-moisture barley than on dry-rolled barley.

High-moisture barley should be rolled for beef cattle. In comparative studies, cattle fed whole high-moisture barley gained 0.3 lb (136 g) less per day, and required 63 units of feed more per unit of gain than cattle whose high-moisture barley was rolled prior to feeding.

F. Popping

Popping is primarily restricted to sorghum grain and is accomplished by the use of gas-fired infrared generators, rated at about 50,000 BTU per hour, each, suspended above the table to heat the grain as it passes beneath. The percentage of milo that will actually pop ranges from 13 to 45% and appears to be influenced by the moisture content of the grain, the temperature within the machine, and the rate of flow through the machine. As moisture content of the grain increases, the percentage of popping increases.

Riggs *et al.* (1970) made an in-depth study of the effect of popping on nutritional value. Four types of popping were compared: rolled (unpopped), normal run (13–45% popped), 100% popped, and partially popped, or that fraction left over from screening out the 100% popped fraction. The processed milos were self-fed in a mixture composed of 92% milo, 7% cottonseed meal, and minerals.

The most striking feature of these data is the great reduction in dry matter consumption of all three groups fed popped milo (Table 6.4). Steers fed rolled dry milo consumed 19 to 37% more dry matter per day than those fed popped milo. The reduction in feed intake was accompanied by improved feed utilization but also decreased daily gain.

Digestibility studies explain some of the reasons for the improvement in efficiency of feed conversion for the popped milo. It should be noted from Table 6.4 that digestion of the nitrogen-free extract (NFE) was approximately 26% greater (61% for rolled versus an average of 77% for popped). Since NFE represents nearly 73% of milo, a 26% increase in digestibility would enhance its utilization tremendously.

The decline in dry matter consumption of popped milo has a very logical explanation (Table 6.5). From the data in that table, it may be observed that the

TABLE 6.4

Comparative Feeding Value of Rolled and Popped Milo[a]

Milo treatment	Daily gain		Daily feed		Nutrient digestibility (%)			
	lb	kg	lb	kg	Feed efficiency	Dry matter	Crude protein	NFE[b]
Rolled	3.10	1.4	21.2	9.6	6.9	57	39	61
Normal, popped	2.73	1.2	14.9	6.8	5.5	75	39	75
100% popped	2.55	1.1	15.1	6.9	5.9	79	38	80
Partially popped	2.75	1.3	17.5	7.3	6.4	76	41	77

[a]Riggs *et al.* (1970).
[b]NFE, nitrogen-free extract.

TABLE 6.5

Effect of Popped Milo on Average Molar Percentage of Volatile Fatty Acid Production in the Rumen[a]

Fatty acids	Rolled milo	Normal popped	100% popped	Partially popped
Acetic	54.9[b]	41.9[c]	44.6[c]	45.5[b,c]
Propionic	30.2[b]	47.6[c]	44.3[c]	42.0[c]
Butyric	8.8	7.8	8.3	8.9
Isovaleric	4.3[b]	1.0[c]	0.5[c]	0.8[c]
Valeric	1.2[b]	1.6[b]	2.4[c]	1.6[b]

Note. Values on same line with differing superscripts differ for acetic, propionic, and isovaleric by $p < 0.01$, and for valeric by $p < 0.05$.

[a]Riggs *et al.* (1970).

feeding of popped milo resulted in greatly increased levels of propionic acid in the rumen. Research data (discussed in a separate chapter) demonstrate that the feeding of the ionophore monensin results in (1) increased production of propionic acid in the rumen, (2) a 10% depression in feed intake, and (3) an approximately 10% increase in efficiency of feed conversion.

G. Pelleting

Pelleting of beef cattle diets attracted considerable interest several years ago. However, very little pelleting of beef cattle diets is practiced anywhere today. Research from the Dixon Springs, Illinois, experiment station showed that pelleting of lower quality hay resulted in greater acceptability and digestibility. However, research has not shown any benefit from pelleting either high-quality hay or high-concentrate diets. Furthermore, the cost of pelleting would require quite large nutritional or economic benefits from such practice in order to justify using that technique of feed processing.

H. Roasting

Corn roasting offers great nutritional benefits as a processing technique for the grain portion of cattle diets. However, because of the cost of heat energy, all processing techniques which require heat (steam flaking, popping, micronizing, roasting, gelatinizing) generally are more expensive to utilize than those using high-moisture grains.

The grain roasting technique, discovered by T. W. Perry in the late 1960s, has been shown to result in an average of 8% more rapid gain, plus a nearly 10% feed saving in beef cattle diets (Table 6.6).

TABLE 6.6

Comparative Performance of Cattle Fed Raw and Roasted Corn, 1970–1975, Six Trials[a]

	1970		1971		1972		1973		1974		1975	
	Raw	300°F (148°C)	Raw	300°F (148°C)	Raw	300°F (148°C)	Raw	300°F (148°C)	Raw	300°F (148°C)	Raw	300°F (148°C)
Number of cattle	91	91	75	75	61	61	25	25	25	25	27	28
Initial weight												
lb	509	513	550	551	507	507	516	518	550	552	524	524
kg	231	233	250	250	230	230	234	235	250	251	238	234
Length of study (days)	112	112	127	127	106	106	191	191	170	170	189	189
Daily gain												
lb	2.33	2.66	2.33	2.47	2.23	2.37	2.34	2.42	2.60	2.73	2.19	2.40
kg	1.06	1.21	1.06	1.03	1.03	1.08	1.06	1.10	1.18	1.24	1.00	1.09
Percentage change		+14		+6		+6		+8		+5		+10
Daily corn												
lb	11.9	12.4	15.1	13.5	13.8	12.9	15.3	15.4	10.4	9.2	15.2	13.8
kg	5.4	5.6	6.9	6.1	6.3	5.9	7.0	7.0	4.7	4.2	6.9	6.3
Dry feed/unit gain	6.8	5.2	7.5	6.4	6.7	6.1	7.6	7.0	7.9	7.4	8.4	7.3
Percentage change		−7.4		−14.7		−9.0		−8.0		−6.0		−13.0

[a]T. W. Perry's summary of Purdue University research data. Average increase in gain due to roasted corn, 8.29%; average decrease in feed required per unit of gain, 9.7%.

Roasting of corn is accomplished by exposing the whole grain to open flame heat. A common model for roasting grain consists of a cylinder housed within a jacket. The inside cylinder has spiral fins on its inside surface which lift the grain through jets of flame pointing downward from the top of the jacket. Many revolutions of the inside drum take the grain through the flames many times until it is heated to 275°F (135°C). Roasted corn has a pleasant "nutty" flavor and aroma, and a puffed, caramelized appearance. Very few of the kernels are actually popped. While raw corn weighs 45 lb/cubic foot, roasted corn weighs only 39 lb/cubic foot, indicating expansion during the roasting process. The moisture content of roasted corn is about 5–9% less than that of raw corn.

Cattle relish roasted corn and tend to "go on feed" more readily than they do on nonroasted (or raw) corn. However, although cattle do not eat any more dry matter on a roasted corn diet, they gain more rapidly, thus causing such cattle to convert dietary dry matter to gain more efficiently.

Another effect observed from feeding roasted corn to finishing cattle is that the carcasses from cattle fed roasted corn grade approximately one-half grade higher than those from cattle fed regular corn.

I. Steam Flaking and Steam Rolling

These two processes are somewhat similar except the former technique is more specific and a longer time is given to the cooking or steaming process. In addition, the flaking process results in elevated moisture content of the grain. In flaking of corn a cooking or steaming time of 12 min at a temperature of 200°F (93°C) will elevate the moisture from 15 to 18%; holding milo at this temperature for 14 min will increase the moisture content from 14 to 20%. Following the cooking process, the grain is passed through rollers set to produce flakes $\frac{1}{32}$ inch ($\frac{1}{13}$ mm) in thickness. As soon as the grain is rolled, it should be dried to approximately 15% moisture. Colorado research (Matsushima and Montgomery, 1967) demonstrated the importance of producing thin flakes in the milling process (Table 6.7, Fig. 6.2).

Cattle fed raw ground corn did gain as rapidly (Table 6.7) as those fed either of the two thicknesses of flaked corn; those fed the thinner-flaked corn gained most rapidly and required the least dry matter per unit of gain.

Flaking of corn increased efficiency of feed conversion over pelleted corn by 5%, and by 10–15% over grinding or cracking in Florida research (Hentges *et al.*, 1966) (Table 6.8).

In Oklahoma research, steam flaking of milo (Totusek *et al.*, 1967) resulted in a nearly 7% increase in feed intake (11.3 vs 10.6 lb/day, or 5.1 vs 4.8 kg) and increased rate of gain (2.63 vs 2.43 lb/day, or 1.2 vs 1.1 kg), but no improvement in efficiency of feed conversion. Hale *et al.* (1966) reported that steam processing and flaking of milo resulted in increased rate of gain (3.10 vs 2.83

TABLE 6.7

Comparative Feeding Value of Corn Steam-Flaked to Different Thicknesses[a]

	Thickness of flakes		Finely ground,
	1/32 inch (1/8 cm)	1/12 inch (1.2 cm)	1/4-inch screen (60 mm)
Number of cattle	14	14	14
Initial weight			
lb	485	483	490
kg	220	220	223
Daily gain (163 days)			
lb	2.82	2.70	2.65
kg	1.28	1.23	1.20
Corn consumed/day			
lb	12.4	12.7	12.8
kg	5.6	5.8	5.8
Units feed/unit gain	6.1	6.7	6.9

[a]Matsushima and Montgomery (1967).

lb/day, or 1.4 vs 1.3 kg), and improved efficiency of feed conversion (7.6 vs 8.0 units of feed per unit of gain). The same investigators reported that steam processing and flaking of barley also resulted in increased gain of cattle (3.10 vs 2.88 lb/day, or 1.4 vs 1.3 kg), but no improvement in efficiency of feed conversion (7.2 vs 7.2 units of feed per unit of gain).

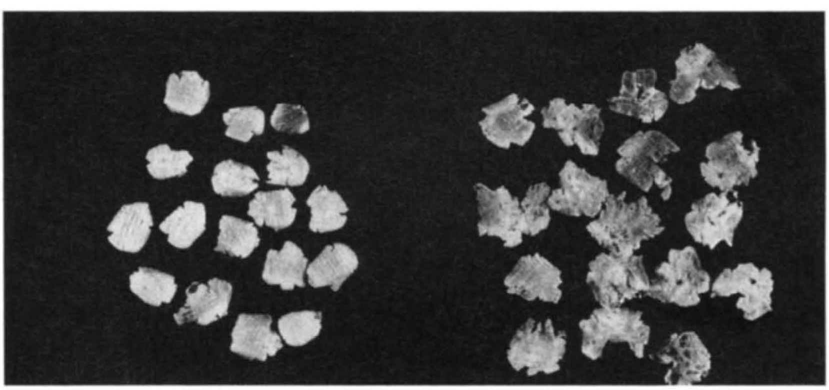

Fig. 6.2 Examples of undesirable (thick flake) and desirable (thin flake) steamed and flaked corn. (Photo courtesy of BEEF Magazine.)

TABLE 6.8

Effect of Grinding, Cracking, Flaking, or Pelleting Corn for Beef Cattle[a]

	Corn treatment			
	Ground	Cracked	Flaked	Pelleted
Number of cattle	20	20	20	20
Initial weight (lb)	588	585	577	588
Daily gain, 126 days (lb)	3.30	3.40	3.60	3.50
Daily concentrates (lb)	18.1	19.5	18.3	18.5
Feed per pound gain (lb)	6.5	6.7	5.8	6.3

[a]Hentges *et al.* (1966).

II. PROCESSING OF ROUGHAGE

Considerable research has been conducted in the area of the value of processing roughage for beef cattle. In general, processing of higher-quality roughage does not result in greater feed intake, improved gain, or improved efficiency of feed conversion; in contrast, some types of roughage processing of poorer quality roughages will improve nutritive value. Such improvement in nutrient value of roughage often is attributed to improved consumption on lower quality roughages. However, because of the low economic value of many roughages, usually it is questionable whether one can afford to spend more than token amounts of time and labor on such practices.

A. Grinding

Grinding of roughages is restricted almost entirely to corn cobs. When properly balanced, ground corn cobs have an energy equivalent to that of medium-quality hay. In contrast, unground cobs have practically no feeding value. Because of the abrasive nature of corn cobs, they are extremely hard on a hammer mill.

Grinding of hay has little nutritive value for beef cattle except as a prerequisite to pelleting or complete mixing of diets. However, the grinding produces so much dust that this causes a feeding problem. Grinding of hay is not practical for dairy cattle because it results in lowered butterfat content of the milk produced.

B. Pelleting

Pelleting of roughages has received a great deal of interest. The Illinois Station at Dixon Springs indicated greatly increased nutritive value of hay as the

result of pelleting. Subsequent research indicated that the benefit from pelleting could be realized only with lower-quality hay—there was no benefit from pelleting high-quality hay.

Pelleting of corn cobs will improve nutritive value; similarly, dehydrating and pelleting whole-plant corn silage will improve its nutritive value. However, the cost of processing such products for pelleting is almost prohibitive.

C. Wafering

Wafering of hay holds considerable promise. In this process the stems are broken somewhat and the resultant product is about 3 inches (7.6 cm) in diameter and 1 to 3 inches (2.5 to 7.6 cm) in thickness. This process has been employed in preparing hay for shipment to other countries, as well as for long distances within the United States; the reduction in volume by such process permits shipment of much greater weights of hay, which in turn may more than pay for the cost of the wafering process.

D. Predigestion, Ammonification

Predigestion using alkali such as NaOH or KOH will increase nutrient availability of low-quality roughages by as much as 33%. Likewise, the ammonification of roughages increases the availability of nutrients and increases the nitrogen (crude protein) content of treated roughages. However, such treatments require much added expense in terms of special equipment, labor, and personal attention.

E. Dehydration

This process is restricted almost entirely to high-quality roughages such as alfalfa. The energy cost is too great to permit its use under other conditions.

F. Ensiling and Hay Making

The use of these processing techniques for roughages is discussed in another section of this text.

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II

Feedingstuffs

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7

Pasture and Forages

Michael J. Cecava

The world's most abundant renewable source of energy is that of pastures and forages. Swine, poultry, and humans are unable to utilize forages to any great extent because monogastrics lack the enzymes needed to degrade fibrous compounds. Fortunately, ruminant animals can utilize this energy through their symbiotic relationship with fiber-fermenting microorganisms in the rumen. Historically, forage has been an important component of beef cattle diets. When averaged over the life cycle, forages compose over 80% of the total feed consumed by beef cattle.

More land area in the United States is in pasture and rangeland production than in all other livestock feeds combined. Furthermore, beef cattle lead all classes of livestock in the consumption of pasture grasses, utilizing about one-third of the permanent pastures and over three-fourths of the range areas. The ranges, pastures, and haycrop land in the United States have a combined area of more than 720 million acres, which is equivalent in size to 20 states the size of Iowa. Only about one-tenth of grazing land is suitable for row-crop cultivation. Consequently, forage utilization by ruminants represents an important means for producing human-edible products from nonarable lands.

I. NUTRITIVE VALUE OF PASTURE AND FORAGES

A variety of factors affect the nutritive value of pastures and forages. Because the estimated nutritive value of plant materials impacts diet formulation and animal productivity, several important factors affecting the nutritive value of pastures and forages are included in this section.

A. Type of Plant

1. Grasses versus Legumes

At the same stage of maturity, legumes generally have higher concentrations of protein and lignin and lower concentrations of cell wall carbohydrates com-

pared with grasses. Feed intake and digestibility are usually greater for legumes versus grasses, probably because of lower cell wall content for legumes. Also, the rate of dry matter and fiber digestion in the rumen may be faster for legumes. Legume crops tend to produce more tonnage of digestible dry matter per acre than many typical pasture grasses. However, there are several drawbacks to legume pasture. First, rather high-quality and high-fertility land is needed for legumes, which entails a high cost assessment per unit weight of dry matter produced. Nearly all legume pasture crops have a tendency to cause bloat in beef cattle, unless such crops are diluted sufficiently with nonleguminous plants. An exception is birdsfoot trefoil, which generally does not cause bloat.

2. Warm-Season versus Cool-Season Grasses

Cool-season grasses tend to be more digestible than warm-season grasses. This is due to anatomical differences in C_3 (cool-season) and C_4 (warm-season) grasses which result in lower digestibility of the C_4 grasses, and to the effects of environmental temperature on cell wall and lignin deposition in C_4 grasses. Higher temperatures may increase the concentrations of these compounds in plant cell walls, thus reducing fiber digestibility. In general, voluntary intake tends to be higher for cattle and sheep grazing cool-season versus warm-season grasses. This may be related to the slower rate of ruminal fiber degradation and passage of material from the rumen when warm season grasses are fed (Minson, 1990).

B. Plant Maturity

Increasing physiological maturity reduces the nutritive value of forages mainly because concentrations of fiber and lignin increase (Table 7.1). This increase is related to a lower proportion of leaves and a higher proportion of stems in plant dry matter (DM) with advancing maturity. Also, the concentration of protein decreases with advancing maturity. Vegetative grasses may contain as much as 15 to 17% crude protein (DM basis) whereas legumes at similar stages of maturity may contain 18 to 22% crude protein (DM basis). With maturity, these concentrations may decline to less than 8 and 13%, respectively (Table 7.2).

The mineral content of plants tends to decline with advancing maturity. However, this is less apparent for calcium compared with phosphorus. The phosphorus content of even mature forage may be sufficient to meet animal allowances except for forages grown on phosphorus-deficient soils or for forages subjected to extreme weathering, especially leaching rains.

The vitamin content of forages decreases with maturity. Growing pasture contains carotene which can be converted to vitamin A by beef cattle. However, mature and bleached forage has very little carotene. The B-complex vitamin concentrations of pastures and forages are quite high in vegetative forage and

TABLE 7.1

Composition, Voluntary Intake by Sheep, and Cell Wall Digestibility of *Phalaris tuberosa* Harvested at Three Stages of Maturity[a]

	Stage of maturity		
	I	II	III
Concentration of cell fractions (% of organic matter)			
Cell wall constituents	43.6	62.8	74.9
Lignin	3.0	4.1	7.4
Soluble carbohydrates	20.9	15.1	11.3
Voluntary intake (g OM/kg $BW^{.75}$)	61.4	53.7	46.3
Digestion of cell wall constituents			
Total tract digestion (% of intake)	82.2	75.8	51.5
Ruminal digestion (% of total tract digestion)	95.3	85.8	75.3

[a]Adapted from Merchen and Bourquin (1994).

decline with maturity. The B-vitamins are of potential significance in beef cattle feeding relative to young calves with incomplete rumen development. Growing plants contain no vitamin D as such. Once vegetation is cut and allowed to sun-cure, a fat-soluble material known as ergosterol is activated by ultraviolet rays to form a calciferol, or vitamin D_2.

TABLE 7.2

Effects of Maturity on the Average Chemical Composition of Alfalfa and Cool-Season Grasses[a]

	Percentage of dry matter		
	CP	ADF	NDF
Alfalfa			
Bud to first flower	>19	<31	<40
First-flower to midbloom	17–19	31–35	40–46
Mid to full bloom	13–16	36–41	46–51
Postbloom +	<13	>41	>51
Grasses[b]			
Vegetative to boot	>18	<33	<55
Boot to early head	13–18	34–38	55–60
Head to milk	8–12	39–41	51–65
Dough +	<8	>41	>65

[a]Adapted from NRC (1982), p 146.
[b]Smooth bromegrass, orchardgrass, reed canarygrass, and tall fescue.

C. Temperature

Forages at high temperatures accumulate more lignin and cell wall carbohydrates than forages of similar physiological maturity and species grown at low temperatures. At low temperatures, a large proportion of total leaf accumulation may be nonstructural carbohydrates, such as fructan, which is highly digestible (Chatterton *et al.*, 1989). This phenomena tends to be more apparent for cool-season grasses than for legumes or warm-season grasses.

Temperature and growing degree days have profound effects on the maturation of forages. Because plant growth and the accumulation of growing degree days are positively correlated, the concentration of fiber and the proportion of stem in forages are also positively correlated with growing degree days. Consequently, quality declines for forage material accumulated over the growing season. However, forage quality can be maintained over the growing season by harvesting accumulated herbage through grazing or haymaking, thereby allowing regrowth to occur.

D. Water Stress

The water concentration of immature forage averages about 75%, depending on species and environmental conditions, and declines with advancing maturity. Both excess and deficiency of water can induce changes in forage yield and quality. Drought is far more common, however. In general, drought has a greater effect on forage yield than on forage quality. The most common effects of drought on forage composition are decreases in neutral detergent fiber concentration and the leaf:stem ratio. The effects of drought on the concentration of nitrogen in forages is contradictory; some researchers have reported increased concentrations while others have observed no change or decline in concentration. The inconsistencies may be related to the degree to which water stress affected leaf growth and the leaf:stem ratio. While the composition of forage may be altered when grown under drought conditions, there appear to be only small effects on digestibility.

E. Soil Fertility

Naturally the yield of forage dry matter per acre is affected by the fertility of the soil. However, the composition may also be affected. Good examples of this point are cobalt and magnesium. Forage crops will grow on soils which are from borderline to markedly deficient in cobalt and magnesium. The crops produced under such conditions will be deficient in either cobalt or magnesium, and so cattle consuming such forages may experience cobalt or magnesium deficiency. These can be corrected with supplemental cobalt or magnesium.

II. TYPES OF PASTURES AND FORAGES

A classification of pastures and forages which designates their general life expectancy and/or general location is provided.

A. Permanent Pastures

This type of pasture is usually found on land that cannot be used for cultivated crops, largely because of topography or moisture. With minimal care, such pastures last indefinitely. Most farms have at least some such land which is fit only for permanent pasture. Most of the rangeland and forest pasture lands come under this category.

B. Rotation Pastures

These pastures are a part of a program of crop rotation. Many years ago it was felt that corn could not be grown continuously on the same land. Therefore several crop rotation programs were studied, such as a 4-year rotation of corn, oats, and clover, respectively. Some such rotation programs covered 5 years; a sod crop, such as clover, was often included. After the first hay crop had been harvested, the clover field was pastured until such time as it was plowed for the following year's corn crop. Inclusion of 1 year's forage crop in corn cropping systems is the exception due to the low economic return from forages compared with that derived from corn or soybeans.

C. Temporary Pastures

Temporary pastures are seeded for use for very short periods of time. They are provided when regular permanent or rotational grazing is not available. Examples are Sudan grass or Sudex seeded in the spring for summer grazing (Fig. 7.1), or oats and rape seeded for spring and summer grazing. Rye may often be seeded following bean or corn harvest for fall and winter grazing (Figs. 7.2 and 7.3).

D. Winter Wheat Pasture

This type of pasture is restricted largely to Kansas, Oklahoma, and other states in the winter wheat belt where cattle are shipped in to graze the wheat which has been seeded for next year's crop. This has a dual benefit in that it provides pasture for the cattle and causes the plant to "stool" out and form a more dense mat of growth.

Fig. 7.1 Sudax, an annual, provides excellent summer grazing. (Photo by J. C. Allen and Son.)

Fig. 7.2 Good pasture plus shade provide an excellent environment for beef cows and calves. (Photo courtesy of BEEF Magazine.)

Fig. 7.3 Brood cows and calves on adequate pasture require only water and supplemental minerals. (Photo by J. C. Allen and Son.)

E. Harvested Crop Residue Material

This is typified by a corn stalk field after the picker–sheller combine has harvested the corn crop. Stalks, pods, and leaves remain after a soybean crop has been harvested. Straw and chaff remain following the combining of small grains. Unfortunately larger and larger farming equipment has resulted in the removal of more and more fences so that many corn stalk fields cannot be pastured.Many attempts have been made to bunch or package corn plant residue for cattle feeding. This has not proven satisfactory except when the corn plant residue is ensiled.

III. PASTURE CROPS

One method of categorizing pasture crops is to divide them into legumes and grasses.

A. Legumes

1. Alfalfa

Alfalfa, or lucerne, as it is called in many parts of Europe, is well adapted to a wide range of climatic and soil conditions. It responds to fertilization and water

along with good cultural practices, including inoculation with nitrogen-fixing bacteria. It is one of the most important forage plants in the United States because it has the highest feeding value of commonly grown forage crops. It produces double the protein produced by clover and many times that produced by the nonlegumes.

Alfalfa is not used commonly as the sole pasture crop for beef cattle because of its bloat-causing effect. It is much more satisfactory as a pasture crop for beef cattle when it is grown in a mixture with nonlegumes, such as bromegrass or orchardgrass, or even bluegrass. Alfalfa can be prone to insect infestation and a variety of diseases associated with bacterial infections so it is often difficult to maintain a stand of alfalfa.

2. Bur Clover and Spotted Bur Clover

These are relatives of alfalfa. They are weak-stemmed plants resembling the clovers. California bur clover contributes to the range pastures of the California and Arizona foothills. In the southeastern states, spotted bur clover is the primary species. All bur clovers are unable to stand the rigors of winter and thus are restricted to more temperate climates. In the western states, bur clover comes up "volunteer" in range pastures whereas in the southern states spotted bur clover must be seeded. However, once seeded, stand life is indefinite.

3. Red Clover

Red clover grows abundantly in the typical Corn Belt country as well as in the entire northeastern quarter of the United States. Furthermore, it grows well as a winter annual in the southeastern United States, and under irrigation in the six or seven far western states. Most varieties grown in the United States fall into the category of "medium" red clover, although Mammoth red clover is also grown quite widely. Red clover is seldom used as the sole pasture crop but rather is grown in mixtures with grasses.

4. Alsike Clover

This is a perennial which contributes to cattle pasture mixtures. Because of its adaptation to wet soils, Alsike is good for establishing pasture sod on wet natural meadows or where irrigation is used. It may persist in bottomlands along creeks or rivers where alfalfa and red clover are unable to survive. It is well adapted to cool climates. It can tolerate greater soil acidity than clover or alfalfa, but nevertheless responds to limestone applications.

5. Ladino and Other White Clovers

These are perennials and are grown widely throughout the world. This group is one of the most nutritious and palatable of all the legumes. The white clovers

are usually grown in association with other legumes or with grass, or with complex mixes of both. Herbage accumulation for Ladino is two to four times greater than that for the white or "Dutch" clovers. The white clovers usually appear as volunteers, especially in the cooler northern pastures; Ladino clover must be seeded. Interestingly, white clover pasture is not very desirable as a horse pasture because it causes excessive salivation or "slobbering" of horses.

6. Lespedezas

The lespedezas are especially well adapted to the southeastern quarter of the United States. It is an excellent summer pasture for all classes of livestock. If grazed sufficiently to prevent the plants from heading, it is very palatable and nutritious. Its maximum carrying capacity comes along at about the time that many of the permanent pasture grasses begin to go dormant. It is an excellent fattening pasture; beef and dairy may gain 2 lb per day on lespedeza pasture. The high quality of the lespedeza pasture may be due at least in part to (a) low water content, (b) extreme palatability, (c) high nutritive value, and (d) the fact that it does not cause bloat. A lespedeza pasture which has matured and has seeds is a very high-energy aftermath roughage for beef cattle.

7. Birdsfoot Trefoil

Essentially grown in the northeastern quarter of the United States and also along a narrow strip of the west coast, birdsfoot trefoil has not had wide acceptance as a pasture legume because of the extremely slow development of its seedlings; in mixtures with clovers and grasses, birdsfoot is not able to compete. It has some resemblance to alfalfa. However, no cases of cattle bloat are known to have occurred on birdsfoot trefoil. It has a wide soil tolerance to fertility and acidity. It is a perennial which reseeds itself, even when grazed closely. It is especially compatible with Kentucky bluegrass, and such stands may stay in existence and in balance for many years.

8. Vetches

The vetches are most common in the southeastern quarter of the United States. There are several varieties of vetch including hairy, madison, common, Hungarian, narrowleaf, purple, and bard. They are especially well adapted as cover crops for land exposed in highway construction because of their matting characteristic. They are usually considered winter annuals, reseeding themselves each year. During this period of the year, land in the southern states is not occupied with cash crops such as cotton or peanuts, and thus the vetches are excellent crops at that time. All vetches are edible and palatable to cattle but only those with hard seed and good seeding habits are recommended for use in permanent pastures. These include hairy and smooth vetches.

B. Grasses

1. Bluegrasses

Characterized by Kentucky bluegrass, these nonlegumes are common in the northeastern quarter of the United States, where there are cooler conditions with adequate rainfall. Bluegrass is adapted to better-drained loams of limestone origin, such as those in Virginia and Kentucky. One of the drawbacks to this pasture grass is the marked periodicity in growth and development: greatly reduced production occurs from mid-July through August. It is well adapted to mixtures with legumes, especially the white clovers and birdsfoot trefoil, but it is too competitive with alfalfa and red clover. It is extremely "washy" in the first few weeks of the spring season, but this tendency disappears within a few weeks. Following its dormancy period in late summer, it responds to fall rains and produces well in September and October. Unpastured bluegrass that is allowed to grow and fall over is a most excellent forage crop for beef cattle in the late fall months.

2. Bromegrasses

These grasses are adapted to cool climates or to regions in which cool seasons prevail for a portion of the season. The Greek derivative *Bromus* signfies oats, and thus the name oats grass often has been applied. There are at least 60 varieties of bromegrass; the most common is smooth bromegrass. The main region of growth in the United States is in the midwestern Corn Belt, but extends quite a bit further north. It is fairly resistant to drought, but in severe drought it becomes dormant much the same as other grasses. Smooth brome is used both alone and in mixtures with other grasses and legumes. In mixtures with legumes, the first cutting often goes for hay, followed then by grazing.

Bromegrass is one of the most palatable of the grasses and maintains its palatability and nutritive value at much later stages of growth than most grasses, except perhaps bluegrass. It produces more aftermath than timothy.

3. Reed Canarygrass

Adapted to the northern portion of the United States and southern Canada, reed canarygrass is especially resistant to flooding conditions and thus is adapted to seeding in gullies, along stream banks, and around farm ponds to prevent water erosion. Its natural habitat is in rather poorly drained pasture areas. It starts growth early in the spring, but it should not be allowed to grow too rank because it loses palatability rapidly. It does not seem to cohabit well with legumes because its shading effect discourages growth of the legumes. An exception here is that Ladino clover will coexist with canarygrass if the grazing and clipping management do not permit excessively tall growth of the canarygrass.

Varying reports have been given regarding its palatability, but most cattlemen report more than satisfactory consumption.

4. Timothy

Timothy is adapted to a cool and humid climate, and thus it is restricted primarily to the northeastern portion of the United States. It is grown primarily for hay but is generally included in pasture seeding mixtures, especially with clover. Such mixtures are generally harvested in the first growth of the year for hay, at the time the timothy heads bloom. Subsequently it can be grazed as a pasture mixture. Young succulent timothy is often relished more than bluegrass by livestock. Timothy is gradually crowded out of permanent pasture by bluegrass.

5. Orchardgrass

Orchardgrass is best adapted in the central United States because of its tendency to winterkill in severe winters. It is able to persist in "thinner" soils than timothy or bluegrass, but responds with greatly increased yields of dry matter upon fertilization. Orchardgrass is a long-lived perennial if conditions are favorable. Its growth in the spring is earlier than that of other grasses, and as much as 3 weeks earlier than timothy. It tends to grow more evenly than the other grasses throughout the drought conditions of summer months.

It is especially used for pasture in the Piedmont and mountain areas of Georgia and North Carolina. In Missouri, it is adapted to a blend with lespedeza and clovers.

6. Bermudagrass

This grass is widely distributed throughout the tropical and subtropical countries of the world, and in the United States it is of prime importance in the southern one-third to one-half of the country. It grows best in areas where the mean temperature is at least 75°F. It is more drought-resistant than some of the other grasses typical of the south. Bermudagrass responds well to fertilization and moisture. It will give the greatest quantity of digestible dry matter under continuous grazing if it is not allowed to grow over 4 to 6 inches tall. In times of most luxuriant growth, it is possible to remove a cutting of Bermudagrass hay; such hay has a feeding value comparable to that of timothy.

7. Dallisgrass and Bahiagrass

These two grasses are adapted primarily to the southeastern United States. Dallisgrass is usually the first grass of the spring season and grows more or less continuously until fall. It cohabits well with a legume and thus provides more uniform grazing for a longer period of time than any other pasture combination. If it is not mowed or grazed judiciously, growth ceases with flowering and seeding.

Bahiagrass ranks intermediate between Bermudagrass and Dallisgrass in productivity and palatability. It is used primarily for pasture on the sandy soils of the

Gulf Coast, and it furnishes little grazing during the winter months. Bahiagrass will stand more frequent harvest with good production than Dallisgrass.

8. Fescue

Fescue is characterized by many species; the two most common varieties are Alta fescue and Kentucky 31 fescue. The fescue group has a wide distribution but the greatest concentration of growth is in the southeastern United States and along the coasts of Oregon and Washington. In the southeast, fescue is especially important as a winter pasture crop and does not persist as well in the hot summer environment. Fescue establishes one of the strongest sods which is thus resistant to breakthroughs from grazing traffic. Its winter growth habits make it important in a grazing program designed for year-round use.

There are some peculiarities about fescues that make it imperative that special management techniques are followed. At certain phases of their growth the fescues become rather unpalatable and cattle will not eat them unless forced. This is caused by an endophyte fungus (*Acremonium coenophialum*) which infects the fescue plant. The fungus has no adverse effects on the plant but causes toxicity in animals grazing infected pastures. There is also the matter of so-called "fescue foot" in which animals grazing fescue tend to become lame.

They will eventually develop a deformed hoof which may slough off.

At the Southern Indiana Center, brood cows grazing fescue pasture appeared to breed, have normal gestation periods, and to produce healthy calves. However, there was little or no mammary development accompanying gestation so that at parturition there was no milk production. Establishment of 15 to 30% legumes in a fescue pasture appears to counteract the periodic toxic aspects of fescue pasture for beef cattle. Furthermore, the feeding of supplemental feed, such as limited hay or energy feeds, also seems to minimize adverse effects.

Fescue pasture perhaps will tolerate more grazing abuse than any other pasture sod. Heavily overgrazed pastures seem to come back with excellent growth after cattle are removed.

9. Wheatgrasses

Grown primarily in the central and northern Great Plains, the intermountain regions, and the Rocky Mountains, wheatgrasses are perennials and cool-season plants grown over several millions of acres of rangeland in the United States. They produce early season grazing in these areas, or as long as the climate remains cool. However, the hot, dry season makes the wheatgrasses essentially dormant. In addition to their grazing potential, the wheatgrasses serve as a deterrent to wind and water erosion. Crested wheatgrass furnishes earlier spring and later fall pasture than native range plants and thus serves to supplement range grazing. Often a hay crop can be cut from crested wheatgrass at about the time it heads out.

10. SORGHUMS

Sorghums for pasture are perhaps best typified by sudan grass and hybrids thereof. The sorghum plants are resistant to drought and thus they are grown primarily in the southern Great Plains area. Sudan grass grows most rapidly in hotter weather when most other pasture crops are dormant. Cattle relish sudan grass. Pasturing of the crop should be delayed until the plants have grown to 18 or 20 inches. Sudan grass is especially adapted to rotation grazing; while one plot is recovering from having been grazed, the other is being grazed into the ground. Because sudan grass stores energy in its roots, there is no danger to the plant in grazing it down to the ground. There is always the potential danger of prussic acid poisoning for cattle consuming sudan grass, but the most critical times are in the early stages (two- and three-leaf stages) or immediately after the plants have been frosted or frozen. Mature sudan grass or that which has been cut for hay or silage has no danger for poisoning cattle.

C. Residue Material

The harvested crop residue materials (straw, chaff, and corn stover) may become somewhat of a problem to dispose of because environmental regulations do not permit massive burning of such products. All of these residues may be picked up from the ground and formed into packages and transported to shelter. However, because residues are by-products of grain and seed production, normally they are left to decay in the field. Residues tend to have low feeding values for cattle, although the potential for much greater value exists. Many researchers have attempted to improve the fiber digestibility of straw, chaff, and stover through chemical treatments and processing. Some of these processes have proven efficacious in improving intake and digestibility of crop residues. However, because residues have such a low economic value initially, it is generally cost prohibitive to transport and process crop residues.

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8

Making Hay and Haylage

Michael J. Cecava

One of the very basics for beef cattle production is optimum use of pasture, especially in cow and calf production. However, because of the diversity of climatic conditions where beef cattle are raised, during many months of the year it is not possible to provide sufficient amounts of nutrients from pasture. Therefore, storage of forage becomes an integral part of such operations.

Forage that is conserved with high amounts of moisture is considered silage or haylage, whereas material that is conserved with lower amounts of moisture is considered hay. The method of forage conservation substantially impacts the nutritive quality of stored material as well as the need for equipment and facilities. This chapter will discuss important points relative to conserving forages for use in beef cattle feeding programs.

I. HAY

A. Stage of Growth and Its Effect on Composition and Yield of Nutrients

Three basic measures of forage production are most desirable, namely, (1) maximum dry matter yield per acre, (2) maximum protein yield per acre, and (3) minimum crude fiber per unit of forage dry matter. Unfortunately, it is almost impossible to combine all three of the above objectives at their respective maximums or minimums. Thus, a compromise among the three is typical. For example, generally, as a forage crop is managed for maximum dry matter yield per acre, the fiber content per unit of dry matter increases. Forages also tend to have decreased concentrations of nitrogen-free extract (NFE) and digestible protein with increasing maturity. The protein components of plants are synthesized when the plant is immature, and as the plant matures the proportion of protein in plant dry matter declines. This is more marked for grasses than for legumes.

The most important factor affecting profitable haymaking is total yield per acre. This occurs because fixed costs, such as labor, depreciation, and mainte-

TABLE 8.1

Effects of Maturity on the Nutrient Composition of Alfalfa[a]

Stage of maturity	CP	ADF	NDF	Digestible DM
		% of dry weight		
Vegetative	>22	<25	<24	>69
Bud	22–20	25–31	34–41	69–65
Early bloom	19–18	32–36	42–46	64–61
Late bloom	17–16	37–40	47–50	60–58
Seed pod	<16	>41	>50	<58

[a]Adapted from Martin (1994).

nance costs, are about the same across yield. A second important factor affecting profitability is managing the first cutting of forage for the highest quality possible. Too often, producers wait too long in making the first cutting of hay and end up with a large yield of relatively low to moderate quality forage.

Alfalfa is a good example of the effects of maturity on nutritive value. Even in the prebloom stage, alfalfa contains about one-third of its dry weight as fiber whereas at the same time the leaves of alfalfa contain only about 12% fiber; by the flowering stage, nearly half of the alfalfa stem is fiber (Table 8.1). This demonstrates how the feeding value of alfalfa hay declines with advancing maturity and underscores the importance of harvesting at the correct time to maintain high-quality forage.

B. Chemical Changes in Hay Drying

Standing alfalfa may contain 4 lb of water for every 1 lb of dry matter. Thus, to produce 1 ton of alfalfa hay with 15% moisture, it would be necessary to remove 6800 lb of water. Rapid drying minimizes nutrient loss whereas prolonged drying can result in great losses of nutrients. Most hay crops are growing actively at the time of cutting. After cutting, cell respiration will continue until the crop has dried to below 40% moisture, resulting in the loss of 3 to 4% of the crop dry matter. Rewetting the cut forage, for example, by overnight dew or light rain, will renew the respiration process. The major nutrients lost during respiration are soluble carbohydrates. Almost all of the sucrose and dextrose may be lost, along with some loss of starch and dextrin if exposure to the weather is prolonged.

The conversion of growing crops into hay does not necessarily result in loss of protein unless the curing and drying process is prolonged, or if there is intermittent raining and drying. However, inevitably there will be conversion of varying

amounts of true protein into nonprotein forms. There is a loss of ether extract but there is no loss of crude fiber or ash.

The loss of vitamins, or of their precursors, is critical. Vitamin A does not exist as such in growing plants, although its precursor(s), in the various forms of carotene, does. Animals can convert carotene to vitamin A, in varying degrees, based upon the type of carotene and species of animal. The carotenes are especially susceptible to destruction in the curing and drying process. Furthermore, the rate of destruction of the carotenes is quite rapid at higher temperatures, higher moisture, and increased exposure to sunlight. In contrast, exposure of hay to sunlight results in the conversion of the vitamin D precursor, ergosterol, to active vitamin D_2 (calciferol). Although B-vitamins are contained in green plants and also in hay, excessive exposure of hay to rains and leaching tends to destroy much of their activity.

C. Losses in Hay Due to Leaching

Rain has very little effect on newly mown herbage because the protective waxy coating on the plant is quite effective. However, when the plant dries, the waxy coating becomes ineffective and the cell walls lose their capability of selective flow of water and nutrients back and forth across the membrane wall. Therefore, rain will dissolve varying degrees of the soluble nutrients, according to the amount of exposure to rain (Table 8.2). In contrast, the concentration of less soluble and less digestible nutrients (e.g., NDF) will be increased.

The loss of nutrients due to leaching may be slight to excessive depending on

TABLE 8.2

Effects of Rain and Stage of Maturity on the Loss of Dry Matter of Alfalfa and Red Clover[a]

Stage of maturity and loss	No rain	Amount of rain in first 24 h after cutting		
		1 inch	1.65 inches	2.5 inches
		% of initial dry weight lost		
Leaf loss				
Bud	7.6	13.6	16.6	17.5
Full bloom	6.3	9.1	16.7	19.8
Respiration and leaching				
Bud	2.0	6.6	30.1	36.9
Full bloom	2.7	4.7	23.5	31.8
Total losses				
Bud	9.6	20.2	46.6	54.4
Full bloom	9.0	13.7	40.2	51.5

[a]Adapted from Mahanna (1994).

the nature of the weather. Records have shown protein losses as high as 25% or more due to leaching; nitrogen-free extract losses may be as high as 35%. Because of the loss of soluble components, rain-leached forage will have higher amounts of fiber than nonleached forage.

D. Making Quality Hay

Harvesting, storing, and feeding hay are an important part of most beef cattle operations. Minimizing losses during forage production and maximizing forage utilization will increase the potential for profitable beef cattle production. Even under the best conditions, 20 to 25% of the dry weight of forage is lost in the process of haymaking. Some of these losses are unavoidable but others can be reduced or eliminated with proper management. The following section will present an overview of procedures that can be used to minimize forage losses and preserve nutrient quality of harvested material.

1. Harvesting at Proper Stage of Maturity

Stage of maturity affects yield, potential intake and digestibility of both grasses and legumes (Fig. 8.1). As hay crops mature, digestibility decreases mostly because fiber content increases. In general, maximum yield of TDN per acre occurs 10 to 15 days before maximum dry matter yield. Stage of maturity at

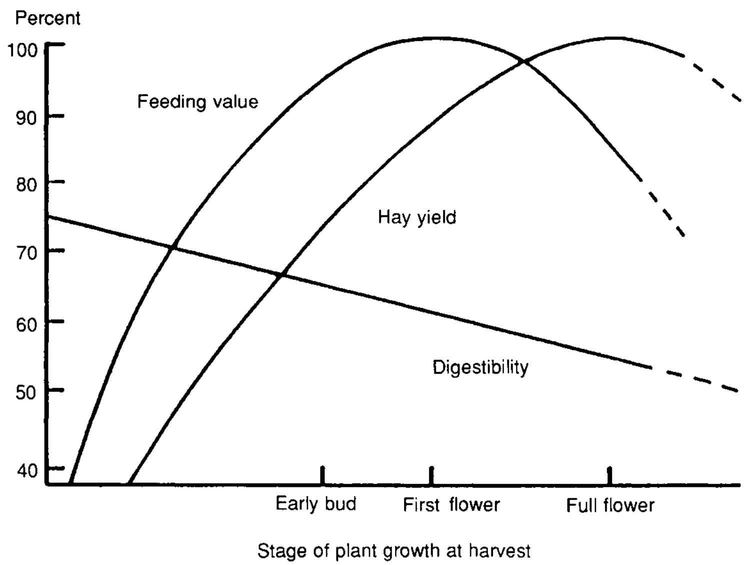

Fig. 8.1 Effects of maturity on the feeding value, yield, and digestiblity of alfalfa hay. Adapted from Ensminger *et al.* (1990).

TABLE 8.3

Effects of Maturity of Alfalfa Hay on Gain and Efficiency of Beef Cattle[a]

Stage of maturity	Average daily gain (kg)	Total gain per steer (kg)	Feed/100 kg of gain
Bud	0.49	43.6	436
1/10 Bloom	0.35	31.4	614
Full bloom	0.29	26.4	727
Seed	0.22	20.0	975

[a]Adapted from Rohweder (1978).

harvest has a dramatic impact on cattle performance, as shown in Table 8.3. Both gain and efficiency were poorer for cattle fed alfalfa harvested at later stages of maturity. The higher fiber content of mature forage slows the rate of feed breakdown in the rumen, thus lowering daily intake. Mature forage also has less soluble carbohydrates and protein on a dry weight basis, so total digestible nutrient content is lower. Intake of poor quality forage can be encouraged by treatments such as grinding and pelleting, but these processes require energy and labor and often reduce nutrient digestibility. Therefore, managing forage for optimum quality at harvest should be a goal of cattle producers involved in haymaking. Table 8.4 provides general guidelines for when to cut forages for maximum digestible nutrient yield.

2. Field Handling

a. Sources of Loss. The largest proportion of nutrient and dry matter loss associated with haymaking occurs during harvest. Harvesting losses are caused by plant respiration after harvesting, rain, and mechanical handling. Machine losses typically account for the largest proportion of field losses, with most loss occurring because of leaf shatter (Table 8.5). This is more true for legumes than for grasses. Alfalfa leaves dry down much faster than stems, and as plant moisture decreases below 30% the leaves become extremely brittle. Leaf loss can have a dramatic impact on the feeding value of alfalfa hay: leaves account for 50% of the plant's dry weight but contain about 65% of the digestible energy and 90% of the plant carotene. Rapid curing, handling the forage as little as possible, and performing mechanical operations when the forage has the correct moisture content are keys to maintaining quality.

b. Mowing and Mechanical Conditioning. Several types of mowers may be used to cut hay, among them the conventional sickle bar, disc and drum cutters, and, more recently, flail cutters. Each type of mower has advantages and

TABLE 8.4

Hay Cutting Guide[a]

Kind of hay	When to cut
Alfalfa	First cutting: bud stage Second and later cuttings: 1/10 bloom
Alsike clover	Early bloom to 1/2 bloom
Bermuda	When 16 to 18 inches tall, before lodging
Birdsfoot trefoil	First flower to full bloom
Bromegrass	Heads emerging
Cowpeas	When pods are 1/2 to fully matured
Crested wheatgrass	When plant begins to head
Crimson clover	From early bloom to 1/2 bloom
Fescue	Boot to early head stage
Grass/legume mixtures	When the legume is at the proper stage
Johnsongrass, millet, sudangrass	40 inches in height or early boot stage
Ladino clover	Few blooms to full bloom
Lespedeza, annual	Early blossom
Orchardgrass	Boot to early head stage
Red clover	Late bud
Sericea	When 12 to 15 inches tall
Small grains (oats, barley, wheat)	Boot stage to early dough stage
Soybeans	Mid-to-full bloom and before bottom leaves fall
Sweet clover	Bud to early flowering
Timothy	Boot to early head stage

[a]Adapted from Ensminger *et al.* (1990).

disadvantages which must be weighed carefully. Whichever mower type is used, it is important to mow early in the day so that forage is exposed to as much solar radiation (sunshine) as possible. Mowing late in the afternoon prolongs plant respiration and increases nutrient loss.

Mechanical conditioning and mowing are typically combined in the same machine. Conditioning devices can be categorized as either roll or flail conditioners. Roll conditioners smash or break plant stems, while flail conditioners abrade the waxy surface of cut forage. Both processes are effective in speeding dry down, but roll conditioners tend to be more effective for alfalfa. Mechanical conditioning does cause additional crop loss (1 to 2% of yield) but proper conditioning can reduce drying time by 50%.

Once the swath has been made, there are three mechanical operations used to increase the rate of drying. These include raking, swath inversion, and tedding. Forage should be raked when it contains about 50% dry matter; raking at more than 50% DM increases the incidence of leaf shatter and nutrient loss. As the name implies, swath inversion involves lifting the forage and gently placing it back on the field surface in an inverted position. In general, swath inversion

TABLE 8.5

Average Losses in Haymaking for a Typical Four-Cutting Hay System (Roanoke, VA)[a]

Type of loss	DM (%)	CP (lb/acre)	Value (dollar/acre)[b]
Field curing losses			
Plant respiration	3.5	0	33
Rain damage	7.9	172	67
Machine losses			
Mowing	2.2	40	11
Tedding	5.1	80	19
Raking narrow swaths	3.7	67	17
Raking following tedding	12.4	205	50
Baling of dry hay	5.6	105	29
Baling of damp hay	4.6	92	19
Storage losses			
Dry hay	3.7	25	37
Damp treated hay	6.5	47	68

[a]Adapted from Rotz (1992).
[b]Value of loss when hay is priced in proportion to its relative feed value with an average price of $90/ton of DM.

causes less shatter loss compared with tedding but is not as effective in improving drying rate. Tedding, or fluffing the swath, may aid in maintaining a loose structure and maximizing surface area. Tedding should be done soon after mowing or early in the day so that sufficient moisture remains to minimize leaf loss.

c. Chemical Conditioners. Organic chemicals are available for increasing the drying rate of forages. They act upon the waxy cutin layer of plants and are effective in increasing the rate of moisture loss from plant cells. In general, chemical conditioners are more effective for legumes than for grasses and less effective on first cuttings than on subsequent cuttings. Potassium carbonate and sodium carbonate can be applied at the rate of 5 to 7 lb of active ingredient in 30 gallons of water per acre. Chemical conditioners may be economical if the possibility of rain damage is great. Otherwise, the return on investment relative to improvements in feeding value appears small.

3. Baling Hay

A popular option for cattle producers is to bale hay in large round bales. Round balers cost more than conventional square balers but they tend to have greater harvest capacity and lower labor requirement. However, large round bales sell for $10 to 20 less per ton than small bales. Consequently, it is difficult to justify producing large round bales for commercial hay sale.

TABLE 8.6

Hay Storage Guide

Storage method	Proper moisture content (%)
Loose	25
Chopped	18 to 22
Small square bales	<20
Large round bales	<18
Large square bales	<16
Cubed	16 to 17

Hay should be baled at the proper moisture level to maintain feeding value. The proper moisture contents for hay depending on type of storage are shown in Table 8.6. The moisture content of cut forage can be estimated by twisting a wisp of hay in the hand. If the stems are slightly brittle and there is no evidence of moisture on the twisted stems, the hay can be safely stored. A second method to estimate moisture content is to scrape the outside of the stems with a thumbnail or knife. If the epidermis can be peeled from the stem, the hay is not safe to store. If the epidermis does not peel off, the hay is usually sufficiently dry. The most accurate method is to use an inexpensive forage tester or microwave oven to rapidly determine the moisture content of cut forage.

If hay is stored at higher moisture contents and not protected with chemical preservatives, heating may occur. Heat is a direct result of microbial growth, specifically the growth of aerobic bacteria and fungi. Excessive heating reduces the digestibility of protein and energy. Under normal conditions, less than 5% of the total protein in forage should be in the form of acid detergent insoluble nitrogen (ADIN). Acid detergent insoluble nitrogen in forages is largely indigestible. It has been estimated that protein digestibility may be reduced by 10% for every 5% increase in ADIN expressed as a percentage of total nitrogen.

The growth of molds in improperly stored hay can reduce acceptability and feeding value. However, it is estimated that only about 5% of the molds commonly found in hay produce mycotoxins. Feeding moldy hay often results in lower dry matter intake, reduced weight gains or milk production, and poor efficiency compared with mold-free hay.

Hay should be protected from weathering by storage in a barn or by covering. Most weather deterioration is limited to the outside layer of the bale and at the soil surface. The amount of spoilage that occurs during outside storage of large round bales can be substantial (Table 8.7). Ideally, hay should be stored in a barn. Hay stored outdoors should be elevated on stone, pallets, tires, or other objects to prevent ground contact. Research conducted in Southern Indiana (Petritz, 1988) showed that large round bales stored in crushed rock had 50% less dry matter loss

TABLE 8.7

Average Losses Due to Spoilage of Large Round Bales Stored Outside[a]

Inches of spoilage	Pounds of spoilage	Percentage of bale spoiled[b]
2	135	12
4	260	23
6	380	33
8	490	43
10	590	51

[a]Adapted from Watson (1994).
[b]Assuming a large bale measuring 5.5 foot by 5.5 foot, 1150 lb, and 8 lb per cubic foot.

compared with bales stored on the ground. Schultheis (1992) calculated that when hay is worth $40 or more per ton and the outer 4 inches is damaged by weather, then it is cost effective within a 3-year period to store the hay on crushed rock and cover it with canvas tarpaulin. If the hay is worth more than $60 per ton and the outer 5 inches is weather-damaged, then it is economically justifiable to construct a pole barn for hay storage.

4. Preserving Moist Hay

When hay is baled above 20% moisture, steps should be taken to prevent microbial growth. Baling moist hay can reduce field losses because leaves are less brittle. Rain damage also may be avoided by baling hay early. However, hay that is baled with excessive moisture will heat quickly because of microbial growth, so a preservative must be added.

A variety of substances have been used as hay preservatives. These include anhydrous ammonia, urea, organic acids, and microbial inoculants. Anhydrous ammonia is a highly effective preservative but it is hazardous to work with and can cause animal toxicity if used improperly. For these reasons, ammonia treatment is not highly recommended. Urea is less hazardous but has not proven as effective. To be effective in reducing mold growth, urea should be applied at the rate of 80 lb per ton of hay.

Propionic acid and other organic acids are effective in preserving hay. Acid treatment reduces mold growth and heating by reducing the pH of stored forage. The recommended application rates of propionic acid are as follows: hay with 20 to 25% moisture, 10 lb of active ingredient per ton; hay with 25 to 30% moisture, 20 lb of active ingredient per ton. For hay with greater than 30% moisture, acid treatment is ineffective. Acid products are not widely used because they are corrosive to equipment and pose a health hazard. Buffered acid products, such as ammonium propionate, are easier to work with and appear to be as effective as

the acid-based products. Acid products are probably only economical if the threat of rain damage is high.

Anaerobic bacterial inoculants have shown limited effectiveness as hay preservatives. Research has shown these products to be more effective in arid regions of the country, where the rate of forage dry-down is faster, compared with more humid climates. These products were originally developed to aid in the fermentation of silage and typically contain lactic acid-producing bacteria. The cost of treatment with anaerobic inoculants is generally about $2 to $3 per ton of hay.

Aerobic bacterial inoculants contain spore-forming bacteria that are adapted to growth in environments containing limited amounts of water, such as in baled hay. Aerobic inoculants contain species of bacteria, such as *Bacillus pumulus*, that are typically found in hay. When applied to hay containing 20 to 25% moisture, aerobic inoculants have improved leaf retention, animal acceptability, and visual quality of the forage. Treatment costs about $3 per ton of hay.

II. HAYLAGE

Haylage is defined as any crop ensiled at approximately 40 to 50% moisture. The most common crops utilized in haylage making are the recognized forage crops, such as alfalfa and similar legumes, and forage grasses including orchardgrass, timothy, sudan grass, and even immature small grains, such as oats or wheat. The most distinguishing characteristic of haylage compared with silage is its moisture content. Whereas most haylages are processed to contain 40 to 50% moisture, most silages contain from 60% up to 70 or 75% moisture. The fermentation processes which occur in the ensiling process will be discussed in detail in Chapter 9, as they are similar for both haylages and silages.

A. Moisture Content of Haylage

The processing of forage crops to attain a maximum of 40 to 50% moisture is defined as wilting. The reduction in moisture content by 10 to 15% after cutting may occur in 3 to 4 h on a good drying day and up to 1 day under poor drying conditions. The most common problem in preserving forage quality when haylage is made is that producers allow excessive wilting to occur before ensiling. When haylage is ensiled drier than recommended, it is difficult to exclude oxygen, and excessive heating will occur because of the activity of aerobic microorganisms.

Ideally, haylage should be ensiled at 62 to 65% moisture in upright silos and 65 to 72% moisture in bunker silos. If haylage is stored in an oxygen-limiting upright silo, then the material may be wilted to reduce moisture to 40 to 55%. It is more difficult to make good low-moisture haylage because leaf loss during

harvest is greater and excessive heating is more likely than for material that is ensiled with higher moisture contents.

B. Chop Length

Haylage should be chopped to theoretical lengths between $\frac{1}{4}$ and $\frac{1}{2}$ inch, with $\frac{3}{8}$-inch theoretical chop appropriate for most forages. When a $\frac{3}{8}$-inch chop length is used, about 15 to 20% of the particles will be greater than $1\frac{1}{2}$-inch long. Having some long particles is important to encourage chewing and stimulate rumen function when the haylage is fed. However, the material must be chopped finely enough to pack well in the silo or bunker so that oxygen is excluded and fermentation occurs properly.

C. Additives

Several types of products can be added to aid the ensiling process. The most common include bacterial inoculants, acid, nonprotein nitrogen sources (urea), and enzymes. A few additives have consistently improved the feeding value of ensiled material whereas other additives are generally not cost effective. When additives are effective, greater feeding value of haylage or silage is realized by improvements in forage acceptability and (or) improvements in digestibility of the forage fiber. A more complete description of additives and their merits will be discussed in Chapter 9.

D. Storage

Silos should be filled as rapidly as possible to exclude air and avoid spoilage. Bunker and trench silos should be packed well and covered with plastic that is weighted down with tires or other heavy objects. Haylage can be stored at 62 to 65% moisture in large bags ("Ag Bags") having a typical capacity of 150 tons. The quality of bagged haylage is related to how tightly the bag can be filled and whether tears in the plastic are avoided. Haylage can be stored in round bale form using baling equipment already present on many farms. The recommended moisture for round bale forage is between 40 and 60%, which covers the range between wilted silage and haylage. The forage is wrapped tightly in plastic with the goal of minimal tearing or puncture of the wrap. If oxygen is allowed to enter, spoilage can be extremely high. Researchers at the University of Missouri (Jonsson *et al.*, 1990) showed that forage should be bagged within 8 h after baling to avoid heating and growth of undesirable organisms.

When forage is preserved as haylage, most of the losses of material occur during storage and feed out. Some of these losses are associated with seepage, or loss of water-soluble nutrients, whereas other losses are associated with spoilage

or heat damage. Losses are highly variable and dependent upon the quality of material ensiled and management and feeding conditions.

E. Choice of Crops

Crops which are desirable for haylage making are numerous. However, a few which are commonly used include alfalfa, clover, oats, wheat, barley, and several grasses. The feeding value of haylage is highly dependent upon the quality of material that was ensiled. Therefore, care should be taken to ensure a high-quality product by harvesting at the optimum stage of maturity.

Alfalfa should be harvested when the plants are approximately one-tenth bloom. Fortunately, alfalfa and clover have a much longer period of optimal harvesting for a high-quality product. On the other hand, the cereal grains, such as oats and wheat, have a very short period for optimum harvest for haylage making, more in the range of 2 to 3 days. Oats and wheat need to be cut at the "soft dough" stage of the grain, and this condition does not persist very long.

Considerable research has been conducted using oats as a hay or silage crop. In fact, the practice of harvesting the entire oat crop in the early dough stage and drying it in the swath for haymaking is a fairly well-established practice. In the 1950s, the University of Illinois published research showing the increased feeding potential of oats harvested as full-moisture (nonwilted) silage. However, farmers have not followed the practice of ensiling full-moisture crops except for corn and grain sorghum.

With the advent of more sophisticated, limited-oxygen storage systems of ensiling, the system of wilting forages to approximately 50% moisture before ensiling became plausible and is now practiced by some farmers. As indicated earlier in this chapter, alfalfa was the principal crop to be treated in this manner. Dairymen especially prefer alfalfa haylage in lactation rations as milk production and feed intake often are greater for cows fed alfalfa haylage than for cows fed with alfalfa hay or silage.

Oats are grown in many areas of the country as a grain. In South Dakota, total acres planted to oats exceed those planted to all other feed grains except corn. Naturally the question should arise of how best to harvest, store, and feed the oats. South Dakota State University (Anonymous, 1977) conducted research to identify the value of oat haylage. In this research trial, stage of maturity of the grain varied from the milk stage in areas of adequate moisture to late dough stage for drier areas. The forage was baled for hay or chopped and ensiled. Moisture content at time of storage was 13% for hay and 52% for haylage; protein content was 16.6 and 16.3%, respectively, on a dry matter basis. Growing steers (673 lb initially) were fed hay or haylage in sufficient amounts to ensure that feed would be available at all times. Dry matter intake was comparable for cattle fed oat hay compared with haylage but cattle fed haylage gained 28% faster (2.28 versus

1.78 lb per day) and had better feed conversion. These data underscore the advantages of preserving forage as haylage in some situations.

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9

Silage and Crops for Silage

Michael J. Cecava

The production and use of silages is especially adaptable in the beef cattle feeding operation. There are many economic advantages to the use of silage. Total digestible nutrient yield per acre is 30 to 50% greater when corn is harvested as silage compared with harvesting as grain and stover. Ensiled crops can be kept for long periods of time without significant loss in nutritive value. Crops can be harvested early to clear the land for fall plowing or for second cropping. Silage requires about three times less storage space per unit of dry matter compared with dry forage, even when the dry material is chopped or baled. There is less wastage of feed when silage is fed compared with feeding dry stalks or hay, and the feeding process lends itself to automation. Finally, it is a palatable feedstuff that is readily consumed by cattle.

There are disadvantages to ensiling crops. One disadvantage is that special storage structures are required for optimum ensiling to occur. Second, because of the high moisture content compared with hay or dry feeds, more total weight must be handled in the feeding process. Finally, ensiling whole plants reduces the amount of organic matter returned to the soil and potentially increases soil erosion.

I. SILAGE-MAKING

The most important factor influencing the quality of ensiled material is the degree to which oxygen is excluded from the silo. The principle of silage making is to exclude oxygen as quickly as possible so that anaerobic fermentation takes place. The more rapidly fermentation proceeds, the greater the amount of nutrients retained in the silage.

A. Phases during Ensiling

The ensiling process takes 2 to 3 weeks, during which time the ensiled material goes through six phases. These phases are described below.

1. Phase I

In phase I, aerobic respiration predominates. The plant cells and aerobic bacteria which are present continue to utilize oxygen and consume soluble carbohydrates, producing CO_2, H_2O, and heat. Available oxygen is usually consumed in about 4 to 5 h after ensiling, at which time the desired anaerobic conditions prevail. It is important to minimize the length of phase I because the production of heat and H_2O can reduce silage quality and oxidation of soluble carbohydrates reduces the amount available to desirable anaerobic microbes. Plant proteins are degraded to amino acids and then to ammonia, with up to 50% of plant protein being degraded during this phase. As the ensiling process proceeds and pH declines, the activity of enzymes involved in proteolysis is greatly reduced. If forage is ensiled too dry, heating may occur. With excessive heating a nonenzymatic process, called the Maillard reaction, causes protein to form an indigestible complex with certain carbohydrates. This lowers both the digestible energy and the protein content of the forage. Therefore, to produce high-quality silage, it is important to minimize the length of phase I by harvesting material at the proper maturity and by following good management practices during ensiling. These will be discussed in the next section.

2. Phase II

Phase II begins after oxygen has been depleted. During phase II, anaerobic bacteria ferment soluble carbohydrates and some protein, producing mostly acetic acid as an end product. With acid production, the pH declines to about 5.0 and the acetic acid bacteria decline in numbers. Normally, phase II lasts about 24 to 72 h. This phase is important because it creates desirable conditions for the following phases of fermentation.

3. Phases III and IV

Anaerobic bacteria which produce lactic acid as an end product of carbohydrate fermentation predominate during these phases. Lactic acid is the most desirable acid found in ensiled material and will compose 4 to 10% of the total dry matter when ensiling is complete. When the silage is fed, cattle can use the lactic acid as an energy substrate. When the pH of ensiled material declines to about 4.2 or less, microbial activity ceases, and the material will keep indefinitely if exposure to oxygen is minimal. Phase IV is completed about 21 days after the silo was filled. If forage is ensiled too wet (>70% moisture) then clostridial bacteria, which produce butyric acid, will predominate in phase IV. Butyric acid production will result in spoiled silage which has low feeding value.

4. Phase V

Ensiled forage is stable during this phase. The final pH of corn silage will be about 4.0 whereas alfalfa haylage will have a pH of about 4.5. The material will remain in this phase until feedout.

TABLE 9.1

Estimated Losses from Silage Storage Systems[a]

Source of dry matter loss	Horizontal trench or stack 35%	Horizontal bunker 35%	Concrete tower 35%	Oxygen-limiting tower 55%	Bag 35%	Round bale 35%
	% of standing crop DM in the field					
Respiration and weathering	4	4	4	6	4	4
Harvesting	2	2	2	3	2	4
Storage	15	12	9	5	7	18
Feedout	4	4	2	2	4	4
Total	25	22	17	16	17	30

[a]Adapted from Bolsen *et al.* (1991).

5. Phase VI

During phase VI, silage is removed from the storage structure and fed. This phase is important because a considerable amount of silage is lost due to secondary aerobic decomposition. Yeasts and molds which cause spoilage can be prevalent if good feeding practices and bunk management are not practiced. It has been estimated that about as much or more silage dry matter is lost in this phase as during the harvesting process (Table 9.1).

B. Harvesting and Processing Recommendations

The key to making quality silage is to proceed from phase I to later phases in the ensiling process as quickly as possible. Doing so preserves the feeding value of the harvested forage. Table 9.2 gives general recommendations for maturity and moisture contents of crops typically harvested for silage-making. The length of cut also is given. These recommendations are based upon creating conditions which promote proper ensiling, namely, sufficient sugar content in the ensiled material for growth of desirable organisms and proper moisture content and chop length for good packing and exclusion of oxygen.

It is relatively easy to produce a highly acceptable feedstuff in the form of whole-plant corn silage. When ensiled at the appropriate maturity, the soluble carbohydrate (sugars, starch) content of corn is such that desired fermentation occurs. Sometimes there may not be enough natural sugars in legumes for good silage-making so it may be necessary either to add a soluble carbohydrate source, such as cracked shelled corn (200 lb per ton of silage), or else to wilt such crops down to about 50% moisture before ensiling (see Chapter 8 concerning haylage-making).

It is important to fill the silo or bunker rapidly to prevent excessive plant

TABLE 9.2

Harvest and Processing Recommendations for Ensiling Forage Crops[a]

Crop	Maturity	Silo type			Length of cut, inches
		Bunker	Stave	Sealed	
			% moisture		
Corn silage	Milk line 1/2 to 2/3 down kernel	67–72	63–68	50–60	3/8–1/2
Alfalfa	Mid-bud to 1/10 bloom, wilt to . . .	65–70	60–65	50–60	1/4–3/8
Cereal silage	Milk or soft dough, wilt to . . .	67–72	63–68	50–60	1/4–3/8
Grasses	Stems first head out, wilt to . . .	67–72	63–68	50–60	1/4–3/8
Clover	1/4 to 1/2 bloom, wilt to . . .	67–72	63–68	50–60	1/4–3/8
Forage sorghum	Medium-hard dough or as leaves begin to lose color	70–75	65–70	50–60	3/8–1/2
Sorghum sudan-grass	3 to 4 feet high	70–75	65–70	50–60	3/8–1/2
Whole plant grain sorghum	Medium-hard dough grain	67–72	63–68	50–60	3/8–1/2

[a]Mahanna (1994).

respiration and nutrient loss. If a bunker or trench silo is being filled, the material should be compacted as it is being ensiled. A wheeled vehicle, such as a tractor, works well for this purpose. The packed material should be covered immediately with a heavy grade of plastic which is weighted down with tires. Unsealed silage will undergo rapid deterioration which may be slowed somewhat by the use of mold inhibitors. However, heating and loss of nutrients from an unsealed structure can be substantial for corn silage and other ensiled crops (Bolsen *et al.*, 1993).

C. Effects of Maturity on Corn Silage Quality

There is an ideal stage for the harvest of the corn plant for making whole-plant corn silage. Maturity at harvest affects the quality of the ensiled corn plant because it affects the moisture content and amount of grain that has formed. The maturity of corn can best be determined by the milk-line, which is the interface between the liquid and solid portions of the corn kernel. As a rule of thumb, corn silage will have optimum feeding value if harvested when the milk line is one-half to two-thirds of the way down the kernel. When the milk line is at these stages, whole-plant moisture content will be about 65 to 70%, which is in the optimum range for ensiling.

Maturity has a dramatic impact on the composition and feeding value of corn silage (Table 9.3). As the corn plant matures, the concentration of grain, and

TABLE 9.3

Effects of Maturity on the Composition of Whole-Plant Corn Silage[a]

	1/3 Kernel milkline	2/3 Kernel milkline	Kernel black layer
Dry matter (%)	31.7	39.1	45.4
Grain content (%)	32.4	41.8	46.1
Ear content (%)	40.9	49.8	54.3
Stover content (%)	59.1	50.2	45.8
ADF (%)	27.0	25.3	25.5
NDF (%)	46.3	43.8	44.5
Total sugars (%)	9.8	7.1	6.6
Starch (%)	22.1	28.4	31.0
TDN (%)	66.2	68.4	68.2
In situ DM disappearance (%)	60.3	58.9	56.4
Tons of TDN per acre	7.45	8.10	8.12

[a]Adapted from Mahanna (1994).

hence starch, increases, whereas the concentration of stover, and hence fiber, decreases. When harvested at the proper stage of maturity, yield of digestible nutrients and feeding value should be optimal.

D. Silage Additives

Additives for silage can be categorized as follows: (1) bacterial inoculants, (2) acids, (3) nonprotein nitrogen sources, (4) enzymes, (5) other feeds. Some of these additives have proven efficacious in reducing nutrient loss and improving the feeding value of ensiled crops. Others have shown inconsistent responses and may not be cost effective for routine use. The following sections discuss the merits and application of silage additives.

1. Microbial Inoculants

Microbial inoculants are the most widely used silage additive. Most inoculants contain live strains of bacteria which ferment soluble carbohydrates and produce lactic acid. The lactic acid reduces the pH of the silage and results in a stable product. The effectiveness of silage inoculants depends upon the number of viable organisms already present in the ensiled material and upon the availability of carbohydrates for the microbes.

Generally, treatment of corn silage with microbial additives has given variable responses ranging from no effect to significant improvements in nutrient preservation and animal performance. It appears that the greatest advantage for a microbial additive may be with low-soluble carbohydrate forages, such as le-

gumes. Inoculants will not be effective if forage is harvested at the incorrect stage of maturity or if good ensiling practices are ignored. Inoculant products should be purchased from reputable suppliers that can provide a quality-assured product.

2. Acids

A Finnish scientist (A. I. Vertanen) developed the patented A.I.V. method which uses a mixture of HCl and H_2SO_4. These caustic acids mixed together prevent the growth of the undesirable organisms. However, the expense of adding these products plus the danger of handling these acids make the A.I.V. method of preserving legume silages impractical in this country.

The primary organic acids used today are propionic acid and acetic acid. These acids are much less corrosive to handle and have proven efficacious in preserving the feeding value of forage by inhibiting the growth of undesirable organisms. Organic acids can be added during the ensiling process at the rate of 1% acid to wet forage (e.g., 20 lb of acid per ton of wet forage). The acids are effective mostly in reducing deterioration of the silage during feedout and while in the feed bunk.

3. Nonprotein Nitrogen Sources

Almost all silage feeding is restricted to ruminant animals which have the capability of utilizing limited amounts of nonprotein nitrogen as a source of crude protein. Urea or ammonia can be added to increase the crude protein content of silage and to enhance the production of lactic and acetic acids during the ensiling process.

Urea is generally applied at the rate of 10 to 20 lb per ton of forage whereas ammonia is applied at the rate of 5 to 10 lb per ton. The addition of these amounts of NPN to corn silage will increase the crude protein content by about 50% (from about 8 to 12% crude protein), thus resulting in a feedstuff that meets the protein allowance of cattle in some feeding situations. Urea can be added by spreading over the material in the harvest wagon or as it is being blown into a vertical silo. Ammonia can be added in several forms, including anhydrous, cold-flow application, and in mineral and water solutions.

Corn silage which has been treated with ammonia contains increased concentrations of lactic acid and acetic acid, higher pH, and greater amounts of crude protein. Such silage is more stable than untreated silage when exposed to oxygen. Data from trials in which NPN-treated corn silage was fed are shown in Table 9.4. These data indicate that cattle fed ammonia-treated whole-plant corn silage had similar performance as cattle fed diets supplemented with soybean meal. Michigan State University researchers developed an ammonia-mineral suspension (A.M.S.) to be used as an additive to green-chopped whole-plant corn at the time of ensiling. The product is normally added at a level sufficient to

TABLE 9.4

Growth and Performance of Cattle Fed NPN-Treated Corn Silage (Summary of 14 Trials)

	Daily gain (kg/day)	Feed/gain
Summary of 11 trials		
A.M.S.-treated silage[a]	1.00	7.5
Nontreated silage (SBM supplement)	1.08	7.7
Summary of 3 trials		
Ammonia-treated silage	1.12	6.5
A.M.S.-treated silage[a]	1.17	6.1
Nontreated silage (SBM supplement)	1.16	6.3

[a]Ammonia mineral suspension.

bring the protein content of whole-plant corn silage up to 12.5 to 13% crude protein on a dry matter basis. Table 9.4 shows that cattle fed A.M.S.-treated corn silage had similar rates of gain and efficiency compared with cattle fed soybean-meal supplemented silage diets or ammoniated corn silage diets. Other researchers have shown that cattle fed silage treated with A.M.S. have faster rates of gain and better feed conversion compared with cattle fed nontreated silage. In general, yearling cattle and cattle with low requirements for preformed dietary protein perform better than calves when fed NPN-treated silage.

When ammonia- or urea-added silage is fed, it is important to consider supplementing diets with additional sulfur to maintain a nitrogen:sulfur ratio of 10:1. This can be accomplished by adding calcium sulfate or other sources of sulfur to the silage.

4. Enzymes

Enzyme additives typically are fermentation end-products of yeasts or certain bacteria, or a combination of fermentation end-products and the yeast or bacteria. These additives typically contain yeasts, such as *Aspergillus oryzae* or *Aspergillus niger,* or bacteria, such as *Bacillus subtilus.* These products ostensibly act to increase the concentrations of enzymes needed to degrade the fiber fraction of ensiled material and thereby increase the amount of carbohydrate available for lactic acid-producing organisms. Most commercially available enzyme additives also will contain lactic acid-producing bacteria.

Under certain conditions, there may be benefits to using enzyme additives. These products may improve fermentation characteristics of the silage and reduce nutrient losses. However, they should not be viewed as an alternative to good silage-making practices. No additive will improve the silage quality as

much as harvesting forage at the correct maturity and following good processing practices.

5. Other Feeds

a. Ground Limestone. It was pointed out previously that the principle of silage preservation was the formation of organic acids which prevent the proliferation of undesirable molds and yeasts. In the case of whole-plant corn silage, acid formation proceeds until a pH of approximately 3.8 to 4.0 is reached. The Ohio Experiment Station researchers postulated that if some of the initial acids formed were neutralized with a basic product, such as ground limestone, the acid-forming process in the silo might be extended until the desired pH was reached. This proved to be the case. Subsequent Ohio research with limestone additions to corn silage at the time of ensiling showed that such silage was a slightly better feed than ordinary corn silage. Wherever convenient, the addition of 10 lb of feed-grade limestone per ton of green chopped whole-plant corn at the time of ensiling is a good practice to follow. It may be desirable to add 10 lb each of limestone and urea per ton of forage.

b. Grain and Other Concentrate Feeds. In some situations, silage made from legumes and grasses may be improved by adding grain, such as ground corn, wheat, or barley. The added grain provides a source of available carbohydrates for the lactic acid-producing bacteria and thus improves the fermentation process. Adding grain also can improve the feeding value of the forage by increasing the TDN content of the silage when fed. Depending upon the moisture content of the forage, grain can be added at the rate of 100 to 300 lb per ton of forage at the time of ensiling. If green forage is ensiled at the proper moisture content (see Table 9.2) there likely is no advantage in animal performance for feeding grain-added silage compared with feeding the ensiled forage with grain.

c. Molasses. If the sugar content of green forage is low, there may be advantages to adding molasses during ensiling. This is particularly true for legumes and certain grasses. Adding a source of readily available carbohydrate can improve the production of acetic acid and lactic acid, thus improving the quality of ensiled material. Molasses addition also may improve feed consumption by improving animal acceptability of the silage. For legumes, molasses may be added at the rate of 80 lb per ton of forage, whereas for grasses 40 lb per ton may be added. The molasses may be added in either liquid or dehydrated form, as both are effective in providing sugars. It is probably not necessary to add molasses to wilted forages, such as alfalfa haylage, or to corn silage, because the available carbohydrate concentrations are normally adequate for good fermentation to occur.

E. Preservatives

The addition of preservatives is not necessary with whole-plant corn or sorghum silage because such crops contain sufficient available carbohydrates from which the anaerobic bacteria can manufacture all the preserving acids that are needed. However, preservatives may be desirable for silages made from unwilted legumes and grasses. Although the use of preservatives is not common, reference to them is worthwhile.

1. Sodium Metabisulfite

This is a dry powder which can be added to the green-chopped legume forage at the rate of 8 lb per ton of material. When this chemical is mixed with the wet forage, SO_2 is released as a gas. Sulfur dioxide is an efficacious antibacterial agent and is even used in small quantities to preserve human foods. Extensive experience in the use of sodium metabisulfite in preserving nonwilted legume silage has shown it to be an excellent preservative.

2. Sulfur Dioxide Gas

This product is supplied under pressure in steel cylinders and is administered by releasing such gas via a probe inserted into the packed green-chopped forage at two- to four-layer intervals as the silo is being filled. The operator performing this task must wear a gas mask as sulfur dioxide can be toxic. About 5 lb of SO_2 gas per ton of green-chopped forage is required. It was from the discovery of the preservative effect of SO_2 gas that the more convenient dry sodium metabisulfite method was developed. However, as was indicated above, no form of special preservation of legume forage in the making of silage compares with the wilting to about 50% moisture and then ensiling as haylage.

3. Formic Acid and Formaldehyde

Lactic acid-producing bacteria are tolerant to acidic conditions whereas some of the less desirable bacteria are not. Therefore, the addition of formic acid might permit growth of the lactobacilli but prevent competition by undesirable bacteria. Formaldehyde inhibits fermentation almost completely, particularly during the first few hours following ensiling, because of its bactericidal actions. Thus, it can reduce the loss of soluble sugars which occurs early in fermentation. These products have been used in Germany for a number of years but are prohibited in the United States because formaldehyde is a suspected cancer-causing agent. Furthermore, these products would appear to have limited application in silage-making other than for corn or grain sorghum.

II. SILAGE TROUBLESHOOTING

Because silage is an integral component of many beef cattle feeding operations, it is important to be able to diagnose the common signs of poor quality silage. Most problems can be traced back to improper harvesting or poor packing during ensiling. The most critical factors to consider are provision of adequate sugars for desirable fermentation and exclusion of oxygen by chopping to the correct length and tightly packing in either a horizontal or a vertical silo.

Table 9.5 lists common problems encountered in feeding silage as well as possible causes. In some cases, more than one problem may be encountered; for example, hot silage will likely lead to caramelized or heat-damaged forage. Consequently, when one problem is diagnosed, one should check carefully for others.

III. STORING SILAGE

The type and size of silo should be determined by the amount of silage typically used and the economics of various storage structures. Upright (tower) silos are more expensive compared with horizontal or bunker-type silos (Fig 9.1). Some farmers construct drive-over piles of silage, which when properly constructed represent an inexpensive means of storage (Roach and Kammel, 1990). However, storage losses from piles can be as high as 30% if the silage is not properly packed and protected. Probably the least expensive type of storage structure with minimal storage losses is the trench silo (Fig. 9.2).

To minimize feedout losses, the size of the storage structure should allow adequate removal of silage once the silo is opened. For upright silos, about 2 inches of silage should be removed daily during the winter and about 4 inches should be removed daily during the summer to minimize deterioration of the silage. In bunker silos, about 4 to 6 inches should be removed from the face of the bunker daily.

A. Estimating the Amount of Silage in a Vertical Silo

Often it is desirable to be able to estimate the amount of silage remaining in an upright. Table 9.6 can be used as a guide to estimate the amount of well-eared corn silage remaining in an upright silo. The following steps should be followed:

1. Estimate the actual depth of silage left in the silo.
2. Estimate the original depth of silage in the silo after settling 30 days.
3. Determine the feet of silage removed by subtracting the depth of silage left from the original depth of silage.

TABLE 9.5

Common Silage Problems[a]

Symptom	Possible cause(s)
Hot silage (> 120°F)	Heat is generated by the combustion of plant carbohydrates and oxygen which occurs during extended plant respiration or through the activity of large populations of molds and yeasts. Caused by slow silo filling, air leaks in the silo, slow feedout, low moisture content, long chop length, or poor packing.
Caramelized, dark brown kernels; dark colored haylage with a cooked or tobacco odor	Excessive heat damage. Generally kernels are a dark-brown color which is caused by entrapment of oxygen during silo filling or by air leaks into the silo. Also caused by low moisture content, long chop length, or poor packing.
Moldy silage	Molds only grow in the presence of oxygen. Caused by slow filling, slow feedout, air leaks, long chop length, or poor packing.
Rancid milk odor	Generally caused by clostridial fermentation with the production of butyric acid. Caused by high moisture content, low populations of lactic acid bacteria, or low sugar content of forage.
Vinegar odor	Fermentation dominated by acetic acid-producing bacteria. Caused by high moisture content, low populations of lactic acid bacteria, and low plant sugar content.
Alcohol odor	Fermentation dominated by yeasts which ferment sugars to produce alcohol. Favored by slow feedout, air penetration into silo, and low populations of lactic acid bacteria.
Frozen silage	Caused by high moisture content, extended respiration, and poor fermentation. More of a problem in upright (tower) silos than with horizontal (bunker) silos.
Poor bunklife	Caused by slow feedout, high populations of yeasts and molds, slow fermentation, or ensiling crops at advanced stages of maturity.
Seepage, run-off	Generally caused by ensiling forage with excessive moisture content relative to the type of storage structure used. Can also be caused by dull chopper knives which result in torn and bruised plant tissue.

[a]Adapted from Anonymous (1990).

4. Using Table 9.6, determine the original tonnage of silage (dry matter basis) contained in the silo.
5. Using Table 9.6, determine the amount of silage removed.
6. Calculate the tonnage of silage removed by subtracting the amount of silage removed from the original tonnage.

Fig. 9.1 An earth bank silo that has been in use every year for the past 25 years.

7. Divide the tonnage of dry matter by the moisture content of the silage to calculate the tonnage of silage remaining on an as-fed basis.

As an example, assume that 20 feet of well-eared corn silage (35% dry matter) remains in a silo having a diameter of 16 feet. The original depth of silage was 42 feet when the silo was opened for feeding. Calculate the tonnage of silage remaining on a wet basis.

1. Estimate depth of silage remaining:	20 feet
2. Estimate original depth of silage:	42 feet
3. Calculate feet of silage removed (42 − 20):	22 feet
4. Determine original tonnage of silage before feeding (From Table 9.6 for a 16-foot silo):	62 tons
5. Determine tonnage of silage removed by removal of 22 feet (From Table 9.6 for a 16-foot silo):	28 tons
6. Estimate tonnage of silage dry matter remaining (62 − 28):	34 tons
7. Calculate tonnage of silage remaining on an as-fed basis (34 ÷ .35 or 34 × 2.86):	97 tons

B. Estimating the Amount of Silage in a Horizontal Silo

To estimate the amount of corn or sorghum silage in a trench or bunker silage, one must determine the average cross sectional area of the silo and multiply by the length of the silo to estimate the total volume. The total volume then is

Fig. 9.2 Wherever it is available, corn silage can help lower the cost of many cattle finishing programs. (Photo courtesy of BEEF Magazine.)

multiplied by 35 (the average weight in pounds of 1 cubic foot of corn silage or sorghum silage harvested at 70% moisture) to obtain an estimate of the pounds of silage in the silo.

For example, the amount of silage in a trench silo 8 feet wide at the bottom and 12 feet wide at the top, 8 feet deep, and 60 feet long is calculated as follows.

1. Calculate the average width of the silo [(8 + 12) ÷ 2] = (20 ÷ 2): 10 feet
2. Multiply average silo width by silo depth to get cross-sectional area (10 × 8): 80 $feet^2$
3. Multiply silo cross-sectional area by length of silo or silage remaining (80 $feet^2$ × 60 feet): 4800 $feet^3$

TABLE 9.6

Guide for Estimating the Amount of Silage in a Vertical Silo (Tons of Dry Matter)[a]

Depth of settled silage (feet)	Silo diameter (feet)										
	14	16	18	20	22	24	26	28	30	36	40
5	3	4	5	7	9	10	12	14	16	24	30
10	9	11	15	18	21	26	30	35	40	59	72
20	24	25	33	40	51	58	69	84	102	132	160
22	23	28	37	46	57	66	77	93	112	148	184
24	26	32	41	51	62	73	85	102	121	164	204
26	28	35	45	57	68	80	94	111	131	180	228
28	31	38	49	62	74	87	103	120	140	196	248
30	33	41	52	67	79	94	111	129	150	208	268
32	35	45	56	72	86	102	120	139	161	224	288
34	37	48	61	77	92	109	128	149	172	244	308
36	40	52	64	82	98	116	138	160	183	256	328
38	42	55	69	86	105	123	146	170	194	276	344
40	45	58	73	91	111	130	154	180	205	292	364
42	47	62	77	97	117	138	163	190	217	308	388
44	49	65	81	102	122	146	172	200	229	324	408
46	52	68	85	107	128	154	181	211	241	340	428
48	54	72	90	112	134	162	190	221	253	360	448
50	56	75	94	117	140	170	199	231	265	376	468
52		79	99	122	147	178	208	241	277	396	488
54		82	103	127	153	186	217	251	289	412	508
56		86	107	133	160	194	226	262	301	428	532
58		89	111	138	166	202	235	272	312	444	552
60		93	115	143	173	210	244	282	324	460	572
62				177	180	217	153	191	336	484	708
64				182	186	224	262	303	348	501	728
66				188	193	232	270	313	360	518	752
68				194	199	239	279	324	372	535	776
70				199	205	246	288	334	384	553	796
72					212	254	297	345	396	570	704
74					219	262	306	355	408	587	725
76					226	269	316	366	420	605	747
78					233	277	325	376	432	622	768
80					240	285	334	387	444	640	790

[a]To estimate tons of silage on an as-fed basis, multiply the dry matter tonnage in the table by the factors below.

Moisture of silage (%):	35	40	45	50	55	60	65	70
Multiply weight of dry matter by:	1.54	1.67	1.82	2.00	2.22	2.50	2.86	3.33

4. Multiply volume (feet^3) by 35 lb to get silo capacity or amount of silage remaining:

(4800 feet^3 $\times$ 35 lb per feet^3 = 168,000 lb)

168,000 lb $\div$ 2000 lb/ton: 84 tons

IV. SILAGE DIETS

A. Balancing a Corn Silage Diet

Corn silage alone is not a balanced diet. Therefore, consideration must be given to adding essential nutrients. Because it is a roughage, it is low in digestible energy and feeding silage alone does not support optimum growth rates of beef cattle. Therefore, varying levels of grain may be fed with silage to provide appropriate energy for desired rates of gain or production. Specifics of diet formulation for cattle will be discussed in later chapters.

1. Protein

Because corn silage is deficient in protein, supplemental protein should be provided. Some researchers suggested that supplemental protein from plant sources, such as soybean meal, linseed meal, or cottonseed meal, was superior to that from urea. More recently, researchers indicate that well-formulated high urea protein supplements may be used with corn silage quite satisfactorily. However, much of the research indicates cattle fed high-urea supplements with high-silage diets gain less rapidly than when a natural protein supplement is fed. In general, supplements which contain a combination of NPN and natural protein will provide adequate performance and reasonable cost for cattle fed silage-based diets.

2. Vitamin A

Vitamin A should be included in a corn silage-based diet. Although corn contains a relatively high amount of carotene, it has been demonstrated that beef cattle do not convert carotene to vitamin A very efficiently. Vitamin A may be provided either by feeding from 20,000 to 30,000 IU per pound of ration on a dry matter basis or by intramuscular injection of 1 million IU for each 100 days cattle are on feed. As long as finishing cattle have access to sunlight (from which vitamin D is activated within their bodies) there is no need for supplemental vitamins other than vitamin A.

3. Minerals

Minerals, such as calcium, phosphorus, salt, cobalt, and possibly zinc, should be provided in a supplement. Minerals may be provided in a portion of the diet, or by feeding in a box on a free-choice basis. A good free-choice mineral mix consists of 2 parts dicalcium phosphate to 1 part trace-mineralized salt for cattle fed diets high in corn silage. Additional salt may be provided in a second compartment of the mineral box.

B. Costs of Corn Silage

It is difficult to arrive at a method of calculating the cost of corn silage which is universally acceptable. However, one method is to calculate the cost on the basis of amount of corn contained per ton of corn silage.

The Statistical Reporting Service of the USDA reported average national yield estimates for 1992 of 131.4 bushels of corn per acre and 14.5 tons of whole-plant corn silage per acre. This is equivalent to 9.0 bushels of corn per ton of corn silage. One can multiply the bushels of corn per ton of silage (9.0) by the value of corn in the field ($3.00 per bushel less 35¢ for harvest, drying, and storage = $2.65) to calculate the value of corn silage as follows: 9.0 bushels × $2.65 = $23.85 for the corn contained in 1 ton of silage. Add the cost of harvesting and storing 1 ton of corn silage ($4.00) to arrive at a total value of $27.85 per ton for the corn silage. In general, multiplying the value of corn grain by 9 will be a close estimate of the value of corn silage before harvesting and storage costs are considered. When corn is $2.50 per bushel or less, it is probably more appropriate to multiply the price of corn by a factor of 10 to calculate the value of silage.

V. OTHER SILAGE CROPS

A. Sorghum Silage

Because corn and sorghum may compete for crop acres in some regions, a comparative evaluation of the two crops for ensiling in the whole plant form is desirable. There are basically two types of sorghum, namely the forage and grain types. Forage sorghum has about 80 to 90% of the feeding value of corn silage (Table 9.7). Forage sorghum drys down slowly and care should be exercised to avoid ensiling at moisture contents greater than 75%. Grain sorghum silage tends to have a slightly lower energy value compared with corn silage although researchers have shown performance of cattle fed diets based upon sorghum and corn silage to be comparable. For optimum feeding value, grain sorghum should be harvested at the medium- to hard-dough stage (60 to 68% moisture). If harvested at greater maturity, much of the grain will pass through the animal undigested.

B. Small Grain Silages

A number of cereal crops can be harvested in the late milk or early dough stages and ensiled for cattle feed. The yield of TDN per acre is much less than that for corn silage, but this method of harvest offers some advantages compared with harvesting the crop for grain. Table 9.7 shows the average content of protein and energy of small grain silages compared with corn silage. One of the real

TABLE 9.7

Composition of Various Silages[a]

Silage crop	CP (% of DM)	TDN
Barley	9.0	64.3
Wheat	9.6	63.8
Oats	9.8	60.7
Rye (wilted)	12.8	58.5
Grain sorghum	7.9	55.0
Forage sorghum	9.2	57.9
Corn	8.3	68.0

[a]Adapted from Ensminger *et al.* (1990) and Anonymous (1990).

problems encountered in harvesting the small grain crops for ensiling is that the number of days in which optimum quality is maintained is short, perhaps only 2 to 4 days. Harvesting early results in less than maximum starch deposition in the seeds and harvesting late results in plant lignification and reduced digestibility.

The cereal crops (wheat, barley, and oats) can provide alternate silage sources for beef cattle and may replace at least some of the sorghum and corn silage portions of the diet. Kansas State University researchers (Bolsen and Oltjen, 1977) compared growth rate and efficiency of beef cattle fed diets based upon cereal silages or corn silage. The researchers estimated comparative feeding values for barley, wheat, and oat silage. Using a base of 100 for corn silage, the following relative values were estimated: barley silage (dough stage) 98 ± 6%; wheat silage (dough stage) 81 ± 15%; oat silage (dough stage) 48 ± 2%. These evaluations were based upon 4 barley silages in four trials, 12 wheat silages in five trials, and 2 oat silages in one trial.

Based upon the Kansas research and other research reports, the following are general conclusions regarding the use of cereal crops for silage:

1. Harvesting and feeding cereals as silage produces more beef per acre than the same crop harvested as grain.
2. For the best silage, cereal grains should be ensiled at 60 to 70% moisture.
3. As cereals mature from boot to dough stages, silage yield increases but crude protein content decreases.
4. Harvesting cereal grains in the mid-dough stage results in maximum TDN and beef production per acre.
5. When ensiled at the dough stage of maturity, winter wheat, winter barley, and spring oats have similar yields per acre (6 to 9 tons).
6. Cereal silages are usually about 1 to 2% higher in protein content than corn or sorghum silages.

When fed to growing cattle in high silage rations:

7. Barley and corn silages are about equal in feeding value.
8. Wheat silage supports about 80% the level of performance of corn silage.
9. The higher the grain content of wheat, barley, and oat silages, the higher the feeding value.

When fed to finishing cattle in high grain rations:

10. Wheat and corn silages support similar feedlot performance.

C. Corn Stover Silage

When corn is picker-shelled with a combine and hauled from the field, nearly one-half of the potential feeding value remains in the field as husk, stalk, cob, and some shelled corn. Researchers have demonstrated that green corn stover silage is an excellent feed for beef cattle, and is more nutritious than silage which has been made from the more mature stover. Corn stover should be harvested as soon as possible after the grain is removed to prevent excess moisture loss. The material should be finely chopped ($\frac{1}{4}$ to $\frac{3}{8}$ inches) to ensure good packing. It may be advantageous to add a source of readily available carbohydrates, such as ground corn or molasses, to aid in the fermentation process.

D. Opaque Corn

The improvement in the nutritional value of opaque-2 shelled corn for rats and swine due to the increased concentrations of lysine and tryptophan kindled speculation as to its advantages for ruminants. Researchers (Thomas *et al.*, 1975) examined growth and metabolism of cattle fed opaque-2 whole-plant corn silage compared with regular corn silage and concluded that there was no advantage for feeding opaque-2 silage. In feedlot comparisons, cattle fed regular whole-plant corn silage actually gained faster than cattle fed opaque-2 whole-plant corn silage.

E. Brown Midrib Corn

Corn plants containing the brown midrib (bmr) genes contain less lignin (2.9 versus 4.9%, on a dry matter basis) and fiber compared with normal corn genotypes (Cherney and Cherney, 1994). Because the amount of lignin has a direct bearing on digestibility of plant cell walls by ruminants, researchers have reported 3 to 5% greater dry matter digestibility by cattle fed bmr corn silage compared with normal corn silage. Some studies on voluntary intake have shown higher dry matter intakes by ruminants fed bmr corn silage compared with normal corn silage whereas other studies have shown no difference (Cherney and Cherney,

1991). Generally, a small improvement in cattle performance is noted when bmr corn silage is fed. Because the bmr trait is negatively correlated with grain yield, there is currently little interest in developing commercial hybrids of corn carrying this gene.

F. Blighted and Stress-Damaged Crops

Infection of corn crops with southern corn leaf blight (*Helminthosporium maydis*) reduces yield and may affect feed quality. The plant is killed before normal maturity, the ears are not filled, kernels are small, grain test weight is decreased, and ears may become infected with fungi. Silage making of the entire plant is probably the only hope for salvage of the crop. It is recommended that silage making be instituted just as quickly as possible after the infection has been identified because damage ensues rapidly. The material should be chopped finer than normal and additional water may be added at time of ensiling because one of the characteristic damages of the blight is the drying-out of the plant.

Drought-damaged corn plants can be salvaged in like manner for making maximum possible use of such products. Generally, the feeding value of drought damaged corn silage is about 75 to 90% of normal silage. The potential for high concentrations of nitrates exists in some crops that are stressed by drought or frost. Nitrates accumulate in the lower portion of plants so it is advisable to leave a 12-inch stubble when corn is cut for silage. Silage made from stressed crops should be tested for nitrate concentrations and feeding programs should be modified to reduce the possibility of nitrate toxicity. Table 9.8 gives recommendations for safe levels of nitrates for various feeding situations.

Following stress conditions or during rapid growth, sorghum and sudangrass

TABLE 9.8

Nitrate Levels in Forages for Cattle[a]

Nitrate ion (%)	Nitrate-N (ppm)	Recommendations
0.0 to 0.44	<1000	Safe to feed under all conditions.
0.44 to 0.66	1000 to 5000	Safe to feed to non-pregnant animals. Limit use for pregnant animals to 50% of total ration on a dry matter basis.
0.66 to 0.88	1500 to 2000	Safely fed if limited to 50% of the ration dry matter.
0.88 to 1.54	2000 to 3500	Feed should be limited to 35 to 40% of the total dry matter in the ration. Feeds over 2000 ppm should not be fed to pregnant animals.
1.54 to 1.76	3500 to 4000	Feeds should be limited to 25% of total ration dry matter. Do not feed to pregnant animals.
Over 1.76	>4000	Potentially toxic to all animals. Do not feed.

[a]Adapted from Anonymous (1990).

may accumulate toxic concentrations of prussic acid, which leads to cyanide toxicity. Poisoning can occur when cattle are fed silage made from Piper sudangrass that is less than 18 inches tall at harvest or from sorghum sudangrass less than 30 inches tall at harvest. Forage sorghums should be headed-out before being ensiled. Care should be taken to ensure that forages of the sorghum family are ensiled at the correct maturity to avoid animal poisoning and death.

G. Miscellaneous Feeds

Apple pomace, consisting of the hull, core, peeling, and seeds, contains about 20% dry matter compared with nearly double that (35 to 40%) in whole-plant corn silage. However, on a dry matter basis, the energy value of ensiled apple pomace is about 80% that of corn silage (Rust, 1991). Generally, it is advisable to mix an absorbent dry material with the apple pomace at the time of ensiling in order to prevent excessive nutrient loss from seepage. Rice hulls have often been used at a rate of about 12 parts pomace to 1 part dry hulls. It is important that the use of pesticides on the apple crop be known to avoid contamination of cattle carcasses with chemical residues.

Pea vines from pea canneries are often available in sufficient quantities that they may be ensiled for preservation as cattle feed. The dry matter content may be as high as 24 to 28% and, on a dry matter basis, the concentrations of crude fiber and protein are about 31 and 13%, respectively. Because of its lower energy content, it is worth only about 75% as much as whole-plant corn silage.

Sugar beet tops are often available in large quantities, as a by-product of the sugar beet industry. Although many forms of utilization are possible, one of the best methods of storage is by ensiling. The value will vary widely, primarily due to the variation in moisture content. This product should not represent more than one-half of the total roughage because it has a laxative effect on cattle. Ensiled beet tops blend well with dry roughages, such as hay.

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10

Concentrates for Beef Cattle

Michael J. Cecava

Cattle have the capacity to utilize tremendous quantities of roughage because of the anaerobic microorganisms found in the rumen. Cattle subsisted primarily on forages and roughages as sources of energy and other nutrients for centuries. However, man domesticated cattle and introduced concentrated energy and protein feedstuffs into the ruminant diet. Concentrate feeding was and continues to be attractive from an economic standpoint. Cereal grains and animal and plant proteins can often be used to supply energy and protein at lower cost per nutrient input compared with forages.

The major source of energy concentrates for cattle is cereal grains, primarily corn, grain sorghum, barley, oats, and wheat. The major sources of plant protein concentrates include the oil meals, primarily soybean meal, cottonseed meal, and linseed meal, and by-products of cereal grain processing, such as corn gluten meal, corn gluten feed, distiller's grains, and brewer's grains. The major sources of animal protein concentrates are by-products of the animal processing industry. These include bloodmeal, meat and bone meal, fishmeal, and poultry feathermeal.

Lipids also represent a source of energy used in beef cattle diets. The rendering industry is a source of tallow and lard (grease) commonly fed to growing and finishing cattle. Substantial amounts of lipid from vegetable sources, such as soybean oil, also are used.

Another source of concentrate for beef cattle is molasses. Molasses is a by-product of the sugar industry and the wood processing industry. Beyond the nutritive value of molasses, feed manufacturers and cattle feeders often use molasses to improve the handling and acceptability of manufactured feeds and diets.

This chapter will discuss the use of concentrate feeds as sources of energy and protein in beef cattle feeding programs. Discussion will focus on the characteristics of the major concentrates and protein feedstuffs typically fed to ruminants. For specific information regarding diet formulation, the reader is encouraged to consult later chapters.

I. THE CEREAL GRAINS

Quantitatively, corn grain is the most important cereal concentrate fed to livestock in the United States (Table 10.1). In 1992–93 about 72% of the corn produced in the United States was used domestically and about 70% of this amount was used in livestock feeding (Anonymous, 1994). Beef cattle account for a substantial portion of the grain consumed in the United States (Fig. 10.1). As would be expected, the majority of grain consumption by beef cattle occurs in the feedlot. Almost 90% of all cattle on feed are located in 13 states found primarily in the midwest or high plains regions of the country, where grain is plentiful (Anonymous, 1994).

All of the cereal grains are high in starch and low in fiber. They are rich in energy and generally quite palatable. The highest concentrations of digestible energy are found in corn, grain sorghum, and wheat. Lower energy concentrations are found in barley and oats. Generally, the balance of amino acids is poor for the cereal grains. Notably, grains tend to be deficient in lysine and tryptophan. Corn is especially low in total protein, averaging 7.8 to 9.0% protein on a dry matter basis whereas barley and grain sorghum (Fig. 10.2) may contain 12% protein or greater. Cereal grains are extremely low in calcium but almost adequate in phosphorus relative to the needs of growing cattle.

None of the grains contain vitamin D and only yellow corn contains β-carotene, the precursor of vitamin A. However, research has shown that the conversion of carotene to vitamin A by finishing beef cattle is quite low. Consequently, diets containing high levels of corn grain must be supplemented with vitamin A.

TABLE 10.1

Concentrate Feed Consumption (in Millions of Metric Tons) in the United States[a]

	1991	1992	1993
Annually			
Corn	124.4	134.6	123.2
Grain sorghum	9.4	12.1	11.7
Oats	3.3	3.0	2.7
Barley	5.1	4.1	5.0
Wheat and rye	2.0	4.2	11.0
Oilseed meals	23.5	24.4	24.7
Animal protein feeds	3.0	2.9	2.9
Grain protein feeds	2.7	0.8	0.8
Other by-product feeds	11.6	12.5	12.5
Total	185.0	198.6	194.5

[a]Adapted from Anonymous (1994).

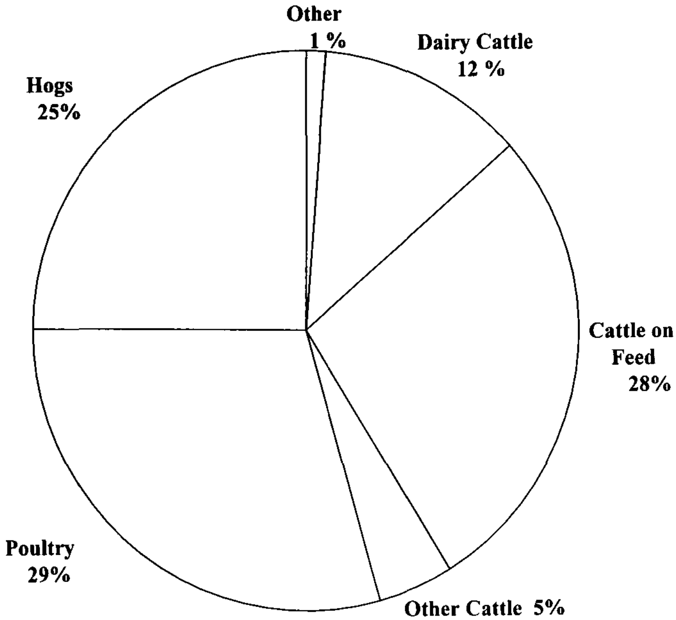

Fig. 10.1 Grain consumption by livestock species in the United States. Adapted from Anonymous (1994).

A. Corn

The hull and the germ are the more well-defined entities of the corn kernel (Fig. 10.3). Just under the hull is a shallow layer, predominantly composed of gluten, which contains most of the protein. Toward the center of the kernel is a mixture of gluten and starch. The corn kernel contains 55% starch, 16% water, and 29% gluten, hull, and germ. Corn oil amounts to about 3% of the kernel weight.

Corn is rich in nitrogen-free extract, nearly all of which is starch. It has the highest concentration of ether extract of all cereal grains except for oats. It is low in fiber and is highly digestible. Corn is the most palatable of all grains for beef cattle and more cattle are finished on corn than on all of the rest of the cereal grains combined.

The yellow color of corn is partly attributable to the carotenes found in the kernel. The characteristic yellow is also attributable to xanthophyll, which is a critical compound for imparting the desirable yellow color to the subcutaneous adipose of chickens.

There is no nutritional justification for grinding air-dry corn for beef cattle, but most nutritionists and cattle feeders recommend at least rolling of ensiled high moisture corn. Almost any kind of heat processing or ensiling of high-

Fig. 10.2 Milo, properly processed, is a most excellent cattle feed. (Photo courtesy of BEEF Magazine.)

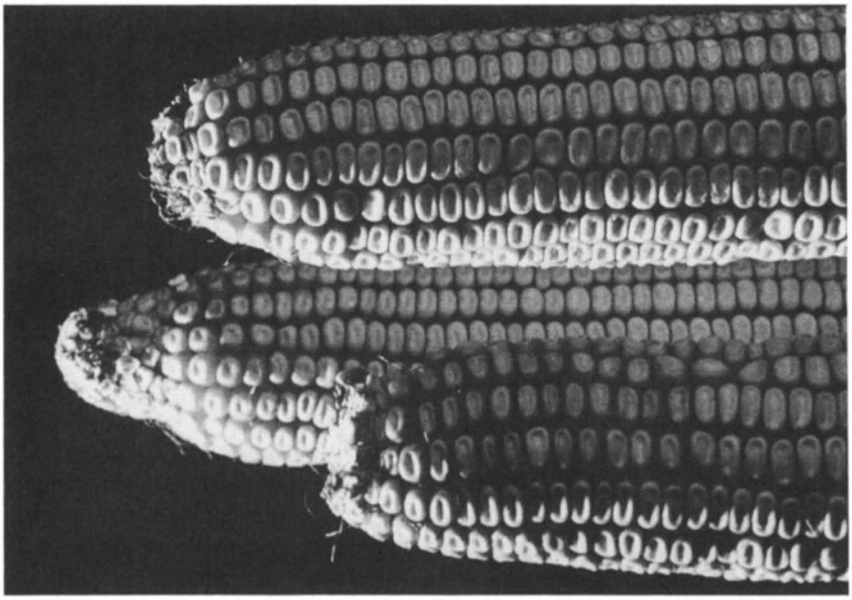

Fig. 10.3 Corn is the No. 1 grain fed to livestock in the United States. (Photo courtesy of BEEF Magazine.)

moisture (25% moisture) corn will improve its nutritive value by about 10%. The reason for this is not clear but cattle feeders should consider roasting, steam flaking, micronizing, or moisturizing corn to increase the digestible energy content.

The stage of maturity at which corn is harvested affects the total nutritive value of the kernel. Note from Table 10.2 that the starch and nitrogen-free extract (NFE) do not approach their maximum concentration until the corn grain is at least at the mid-dent stage. Therefore, unless an early frost, drought, or blight dictates a relatively early harvest, it is best to allow corn to mature for optimum digestible energy content. Because protein deposition occurs early in the maturation process, the protein content of the corn kernel actually decreases with advancing maturity and deposition of starch. Therefore, early harvested corn may have a slightly higher protein content than mature corn.

The by-products of corn grain processing can be utilized as feedstuffs in beef cattle diets. These include corn gluten meal, corn gluten feed, corn germ meal, corn steep liquor, and distiller's dried grains. When competitively priced, by-products can be used to partially replace traditional feedstuffs. The use of by-products will be discussed in the section dealing with miscellaneous concentrate feeds.

TABLE 10.2

Effect of Maturity on the Chemical Composition of Corn Grain[a]

	Early milk	Early dough	Mid-dent	Mature
	Concentration in dry matter			
Dry matter (%)	21	36	55	77
Crude protein (%)	17	13	11	11
Ether extract (%)	3	4	5	5
Crude fiber (%)	5	3	3	2
Ash (%)	3	2	2	1
Nitrogen-free extract (%)	72	78	80	81
Starch (%)	47	55	59	63
Cell walls (%)	28	25	16	14
Gross energy (kcal/kg)	4560	4540	4590	4580

[a]From Goodrich and Meiske (1969).

Corn Types

Many types of corn, such as high-lysine, opaque-2, and waxy maize, have been studied as feedstuffs for beef cattle. In general researchers have concluded that none are quite equivalent to regular hybrids of field corn relative to yield and feeding value for beef cattle.

Several new types of corn have been introduced in the past few years. One of these is waxy corn, which is chemically different from regular corn in that nearly 100% of its starch is in the form of amylopectin (a many-branched molecule) whereas that of normal corn is 25% amylose (an unbranched chain of glucose units) and 75% amylopectin. Because amylopectin is more susceptible to enzymatic attack than amylose, waxy corn varieties tend to be more digestible by cattle compared with normal corn. However, yield per acre is less for waxy corn. Another corn type is opaque-2, or high-lysine corn. High-lysine corn has more lysine than normal corn (0.46 vs 0.28% lysine on a dry matter basis; NRC, 1982), which makes it more nutritious for monogastric animals. However, high-lysine corn is more prone to diseases, and yields are less than those for normal corn. A third type of corn is opaque-2 plus floury-2; this corn contains a combination of genes that results in increased lysine and tryptophan concentrations.

Several researchers have compared corn grain types for beef cattle. The University of Minnesota (Goodrich and Meiske, 1974) compared four types of corn for growing beef cattle (Table 10.3). The cattle fed waxy corn appeared to gain faster than those fed dent corn, but increased consumption of waxy corn resulted in no differences in efficiency of feed conversion. The Minnesota researchers assayed the types of corn for amino acid content and found that opaque-2 corn contained nearly one-third more lysine than regular corn. However, because of

TABLE 10.3

Effect of Type of Corn and Performance of Beef Cattle[a]

	Type of corn			
	Dent	Waxy	Opaque-2	Opaque-2 plus floury-2
Number of steers	16	16	8	8
Initial weight (lb)	680	679	683	672
Final weight (lb)	1077	1103	1083	1043
Gain (lb/day)	2.63	2.81	2.65	2.46
Feed intake				
Corn (lb/day)	15.9	17.6	15.7	14.2
Supplement (lb/day)	0.8	0.9	0.8	0.7
DM intake per pound of gain	5.6	5.6	5.4	5.4

[a]From Goodrich and Meiske (1974).

extensive ruminal fermentation of feed proteins, one should not assume that feeding opaque-2 corn will result in greater lysine supply to the animal.

Researchers at the University of Nebraska (Brady and Farlin, 1978) compared waxy corn with nonwaxy corn in two trials. There was a trend for more efficient gains with the waxy corn. University of Illinois researchers (Wilson *et al.*, 1975) conducted four feeding trials with beef cattle in which waxy corn was compared with nonwaxy corn. In two of the trials, cattle fed waxy corn gained more rapidly, while in the other two trials cattle fed waxy corn gained comparably to those fed nonwaxy corn (Table 10.4). Improvements in rate of gain and feed

TABLE 10.4

Growth Rate and Feed Efficiency of Cattle Fed Waxy or Nonwaxy Corn[a]

Number of animals		Gain (lb/day)	Feed:gain
Steers			
60	Nonwaxy	3.28	6.17
	Waxy	3.65	5.65
48	Nonwaxy	3.39	5.46
	Waxy	3.60	5.32
180	Nonwaxy	2.22	8.93
	Waxy	2.33	8.85
Heifers			
120	Nonwaxy	2.11	6.94
	Waxy	2.09	6.99

[a]Wilson *et al.* (1975).

efficiency by cattle fed waxy varieties of corn are likely related to increased starch digestibility because amylopectin is more susceptible to amylolytic enzymes compared with amylose. Also, there may be improvements in protein digestibility for grains having high amylopectin content.

Purdue University researchers (Thomas *et al.*, 1975) compared the four types of corn in digestion and nitrogen balance studies. Their conclusions were: (1) across dietary protein concentrations, steers fed nonwaxy, waxy, and opaque-2 corn gained similarly; (2) steers fed opaque-2 corn ate the least amount of feed and thus required less feed per pound of gain; and (3) diets containing waxy corn were less digestible. It seems cattle utilize the various types of corn similarly and corn types should be included in the diet on a least-cost basis, irrespective of genetic makeup.

B. Other Concentrates

1. Grain Sorghum

Grain sorghum is an extremely important grain in areas where corn cannot be grown. In most cases, grain sorghum does not compete with corn, but instead represents a cereal crop that can be produced in semiarid areas of the world which are too dry for corn production. Thousands of cattle are finished on grain sorghum in the Great Plains area of Kansas, Oklahoma, and the Texas Panhandle.

The grain sorghums have a general nutrient makeup similar to that of corn, but require more rigorous processing for optimal feeding value. Grain sorghums are high in starch and low in calcium and crude fiber. Compared with corn, the digestible energy content of most varieties tends to be lower but protein content tends to be higher.

The seed coat of grain sorghum is quite hard and therefore it is important that grain sorghum be crushed mechanically before being fed to cattle. Processes such as coarse rolling or grinding are effective in increasing digestibility of grain sorghum by beef cattle. Grain sorghum can be stored in the high-moisture form either through high-moisture harvest or reconstitution. Feed efficiency by cattle fed high-moisture grain sorghum is 10 to 18% greater compared with cattle fed dry grain sorghum. High-moisture grain sorghum should be rolled or ground before feeding. If harvested in the high-moisture state, it can be stored either in the whole or processed form with equal feeding value. However, if dry grain sorghum is reconstituted, it must be stored in the whole form for at least 10 days and preferably for 20 days before feeding to obtain an improvement in efficiency of use.

The method of processing sorghum grain can have dramatic impacts on the feeding value. Texas researchers (Shaake *et al.*, 1972) conducted two feeding trials to study the effect of four processing methods upon animal performance

and carcass characteristics of growing cattle. Cattle fed steam-flaked, whole-reconstituted, and rolled or rolled–reconstituted sorghum grain diets gained similarly and produced carcasses with similar characteristics. Similar results were obtained for cattle fed either steam-flaked or micronized grain sorghum. Cattle fed reconstituted and rolled grain sorghum diets had most efficient feed conversions. The greatest improvement in efficiency of feed conversion from ensiled high-moisture grain is not an uncommon observation in such comparative research. Steam-flaking grain sorghum will improve digestibility and efficiency of feed utilization. Current recommendations are that sorghum should be flaked to a density of 22 to 28 lb/bu. However, feeding highly processed grain sorghum to growing cattle may increase the incidence of acidosis and result in poorer performance compared with feeding less extensively processed sorghum (Reinhardt *et al.*, 1993).

The type of grain sorghum can have a substantial impact on feeding value in beef cattle diets. Waxy varieties or types of sorghum tend to be more digestible than nonwaxy types because of increased concentrations of amylopectin. Hibberd and co-workers (1982) reported that some varieties of sorghum are superior in feeding value and that most of the variation in value was associated with the endosperm type and starch availability. Some varieties of sorghum grains contain high concentrations of condensed tannins that aid in the prevention of preharvest mold growth, grain germination, and bird predation. These varieties are called bird-resistant. Some researchers have shown bird-resistant sorghum to have lower concentrations of available starch and protein compared with normal varieties of sorghum. Tannins may bind to dietary proteins and reduce amino acid supply to the animal. Therefore, there may be some consideration for increasing the protein content of diets containing bird-resistant grain sorghum (Streeter *et al.*, 1993).

2. Barley

Barley is a cool-weather, relatively drought-resistant crop. There are two areas of the United States where these conditions prevail. The northern and north-central regions of the United States (i.e., Minnesota and the Dakotas) are suitable for growing spring barley, whereas winter barley can be grown in California and Arizona. Barley is one of the major cereal crops grown in California.

Barley is usually listed in most feed ingredient tables under two categories; Pacific coast barley, which has an average protein content of 8.7% (dry-matter basis), and non-Pacific coast barley, which has an average protein content of 11 to 12% (Crampton and Harris, 1971). The location where barley is grown, therefore, can have a significant effect upon its feeding value for beef cattle. The TDN content of barley ranges from 75 to 78% (shelled corn has 80% TDN).

Many experiments have been conducted which show that it is critical for barley to be processed before it is fed to beef cattle. For many years this con-

TABLE 10.5

Effect of Processing on the Feeding Value of Grain Sorghum and Barley[a]

	Grain sorghum		Barley	
	Dry-rolled	Steam-flaked	Dry-rolled	Steam-flaked
Number of steers	30	32	32	32
Average initial weight (lb)	572	572	579	576
Gain (lb/day)	2.81	3.12	2.88	3.10
Feed intake (lb/day)	22.4	24.8	20.8	22.7
Feed:gain	8.30	7.92	7.22	7.32

[a]Adapted from Hale *et al.* (1966).

sisted primarily of grinding or dry rolling. However, more sophisticated methods of treating barley include steam flaking and reconstituting. Researchers (Hale *et al.*, 1966) compared dry-rolled and steam-flaked grain sorghum or barley in diets for finishing beef cattle (Table 10.5). Cattle fed steam-flaked barley gained faster and consumed more feed compared with cattle fed dry-rolled barley. Efficiency was similar for the two types of barley and superior to that observed when grain sorghum was fed.

Ensiling of high-moisture barley (25 to 27% moisture) is also an excellent method of processing barley to make it a more valuable feed for beef cattle. The Northwest Experiment Station at Crookston, Minnesota, published a 2-year summary of research on the comparative feeding value of dry and ensiled high-moisture barley. Over 200 head of cattle were involved in this research. Cattle fed high-moisture barley gained an average of 8.6% faster (2.52 versus 2.32 lb/day) and required 9.3% less feed (805 versus 888 lb) per 100 lb of gain than cattle fed dry-rolled barley.

Barley can be used as a substitute for corn when competitively priced. Researchers in South Dakota (Pritchard and Robbins, 1991) reported that substitution of rolled barley for whole shelled corn resulted in slightly decreased rates of gain and feed intake but similar efficiencies of feed utilization by growing beef cattle. The researchers pointed out that because barley has a higher protein content than corn, there is substantial reduction in the costs of protein supplementation when barley is fed.

When barley is processed properly to obtain its maximum feeding potential, it is nearly equal to corn in value. There are some cautions about barley feeding that the inexperienced feeder should note. For instance, cattle tend to bloat more on barley than on other grains. This problem can be reduced by feeding combinations of barley and other grains. Also, cattle tend to tire more quickly on long feedlot periods of barley feeding than is true for corn or for grain sorghum.

3. Wheat

Normally wheat is too expensive to be considered as a livestock feed. However, in some cases the feeding of wheat can be economically justified. An analysis of wheat shows an average of 80% TDN and 10 to 12% protein. Thus, wheat contains about the same digestible energy as corn and 1 or 2% more protein (swine farmers have recognized for years that wheat actually is worth about 5% more than corn for growing and finishing hogs). However, feeding wheat to cattle takes better management than does feeding corn.

The starch found in wheat is rapidly fermented in the rumen compared with the starch found in other grains and this can lead to an accumulation of lactic acid. Cattle may develop "acidosis" or "enterotoxemia" when the production of lactic acid exceeds the rate of utilization. The most severe manifestation of this condition is sudden death. Kansas State University researchers showed that cattle fed certain varieties of wheat had 2 to 4 times more lactic acid accumulation in the rumen than cattle fed corn.

Wheat is an excellent feed for fattening cattle when handled properly. It is suggested that wheat should not replace more than one-third to one-half of the corn in diets fed to fattening cattle. Although it is possible to feed higher levels, the 50% substitution maximum is considered safe. Some cattle feeders who use wheat will include a quarter pound of sodium bicarbonate per head daily which helps to neutralize lactic acid. Cattle should be introduced gradually to diets in a phase-feeding or step-up program. One advantage of substituting wheat for corn in high-concentrate finishing diets is that less supplemental protein is needed to meet animal allowances.

If fed dry, wheat should be ground or rolled before feeding. Wheat lends itself well to ensiling as a high-moisture grain. It should be rolled as it comes out of the silo, just before feeding. The following are management recommendations for successful wheat feeding:

1. Cattle fed high-wheat diets should have feed in front of them at all times to prevent acidosis.
2. In high-grain finishing rations containing only 1 to 3 lb of dry roughage or 5 to 10 lb of corn silage, limit wheat to no more than 30 to 35% of the total ration or a maximum of 50% of the grain portion. For high-roughage growing rations, such as those based upon corn silage, haylage, or hay, all of the supplemental grain in the ration can be wheat if concentrate intake is limited to no more than 1% of animal body weight.
3. Avoid fine dusty particles. The finer the particle size, the more rapidly the wheat starch is fermented in the rumen. A coarse rolled flake is probably the best form because whole wheat is not desirable for beef cattle. Whole wheat tends to get rubbery as it is masticated. Pelleting or adding liquids is not of great help with finely ground wheat because neither slows the rate of ruminal starch fermentation.

4. All-wheat diets appear to be more easily managed in warmer seasons when feed consumption by cattle appears to be more regular compared with consumption patterns during cold weather or during fluctuating environmental pressure or temperature.

5. Exceptional care should be exercised in bringing cattle up to a full feeding on wheat-based diets. The shift should be gradual rather than abrupt.

6. Inclusion of sodium bicarbonate may be beneficial. Sodium bicarbonate neutralizes acids in the rumen and may lessen the severity of acidosis in cattle.

7. Total dietary protein content should be monitored when feeding wheat in place of corn because wheat contains 20 to 25% more protein than corn. The amount of supplemental protein offered should be adjusted accordingly. The supplement should be balanced to provide other nutrients (i.e., vitamins, minerals, and feed additives) in the appropriate amounts.

Kansas researchers demonstrated that wheat is a viable substitute for grain sorghum in diets fed to finishing cattle (Table 10.6). These researchers also reported the benefits of feeding sodium bicarbonate when diets contain high amounts of wheat.

4. Oats

Because of their higher fiber (12%) and lower TDN (69%) content, oats have considerably lower energy content than the previously discussed grains. How-

TABLE 10.6

Growth and Performance of Cattle Fed Wheat as a Substitute for Grain Sorghum[a]

	Rolled grain sorghum	Low wheat	Medium wheat	High wheat	High wheat plus bicarbonate[b]
Feed (lb/day)					
Forage sorghum silage	11.3	10.3	10.2	9.5	9.5
Rolled grain sorghum	19.6	14.8	9.2	0.4	0.4
Rolled wheat	—	4.1	8.9	15.6	16.2
Protein supplement	1.5	1.3	1.1	0.7	0.7
Dehydrated alfalfa meal	0.5	0.5	0.5	0.5	0.5
Ground limestone	0.2	0.2	0.2	0.2	0.2
Air-dry total	25.6	24.4	23.3	20.6	21.2
Initial weight (lb)	885	890	889	887	885
Final weight (lb)	1219	1198	1217	1194	1222
Gain (lb/day)	2.73	2.52	2.69	2.52	2.77
Air-dry feed:gain	9.4	9.7	8.6	8.2	7.6

[a]Brethour (1977).

[b]One hundred grams of sodium bicarbonate fed per head daily.

ever, oats are an excellent source of supplemental energy and protein for cattle, particularly for lightweight cattle and lactating cows. Limited amounts of oats may be included in finishing cattle diets, especially when diets have low levels of roughage. However, oats may not be competitively priced relative to other sources of roughage, such as moderate-quality hay or corn silage.

Oats are considered to have about 80 to 85% the feeding value of corn. However, when oats are used in growing diets or when oats constitute less than 30% of a finishing diet, they may have nearly 100% the feeding value of corn, grain sorghum, or barley.

In growing diets or in brood cow diets where the amount of grain fed is low, it is not necessary to process oats. In finishing diets, it is important to grind or crush the oat kernel, because processing will improve utilization.

5. Rye

Rye is used mainly for pasture or as a cover crop and only small amounts of grain are fed to livestock. Contamination with ergot greatly hinders its use as a feed grain. It is one of the least palatable of all feed grains for livestock.

6. Grain Screenings

Screenings are composed largely of small and broken kernels, hulls, kernel tips, small pieces of cob, dirt, and weed seeds. The nutrient composition can be quite variable depending upon the amount of cob and foreign material. Screenings that are relatively free of dirt and weed seeds will contain nearly as much energy as corn grain and may even be somewhat higher in crude protein.

Feeding management is probably the most important factor to consider when using screenings as a substitute for corn grain. The screenings are usually extremely fine and dusty which may reduce feed intake by cattle. In addition, if cattle are not fed some type of roughage (silage or hay), digestive disorders may be prevalent, particularly for long-fed cattle (>120 days on feed). Care should be taken to ensure that screenings are relatively free of weed seeds. Certain weed seeds are highly toxic when fed to cattle.

To obtain maximum intake and feeding value from corn screenings, these suggestions are offered as guidelines:

1. Feed 25% of the concentrate as regular corn, preferably as whole shelled corn.
2. Feed at least 3 to 4 lb of coarsely chopped or long hay or 10 to 20 lb of silage daily to growing and finishing cattle. Using silage or haylage is better than a dry roughage because this reduces the dustiness of the ration.
3. Dustiness can also be reduced by adding 3 to 5 lb of molasses per 100 lb of screenings.
4. Buy and feed screenings on the basis of weight rather than volume. Screenings have a lower density than grain, thus weight per unit volume is lower.

5. Have the screenings analyzed for crude protein. It may be possible to reduce the amount of supplemental protein required in certain situations.

6. If the amount of supplemental protein offered is reduced, be sure to provide supplemental vitamin A and minerals (especially calcium). It may be practical for some feeders to inject cattle with vitamin A and provide a mineral mix containing equal parts of limestone, dicalcium phosphate, and trace mineralized salt-free choice.

II. MOLASSES

Molasses is a by-product of the sugar, wood and citrus processing industries. Cane and beet molasses are by-products of sugar manufacturing from sugar cane and sugar beets, respectively, whereas citrus molasses is produced from the juice of citrus waste. Wood molasses is produced during paper manufacturing. Because the family of molasses products are commonly used in beef cattle formulations, they will be considered in this chapter.

A. Cane Molasses

"Blackstrap" or cane molasses is a by-product from the manufacture of sugar from sugar cane. The plant is grown worldwide, so the by-product, cane molasses, is shipped great distances, primarily by ocean-going barges. Cane molasses is the residue remaining after as much sugar as possible has been crystallized from sugar cane. It contains about 55% sugar, 6% protein, and 70 to 75% TDN on a dry matter basis. Cane molasses is extremely palatable to beef cattle, and is often included for its dust-settling effect and for the pleasant aroma it imparts to feeds. Cane molasses can be offered on a free-choice basis in a tank, or it may be incorporated into a portion of the ration, as in the protein supplement, or into the total ration. When included in dry diets, molasses should be restricted to less than 10 to 15% of the diet on a dry matter basis. Diets containing higher amounts are difficult to handle and may cause digestive disturbances.

Fattening cattle offered cane molasses on an *ad libitum* basis in a lick tank will consume 2 to 3 lb per head daily, in addition to dry feed consumed. When fed in limited quantities, cane molasses can be fed as an energy source in place of corn. In fact, in quantities up to a maximum of 4 or 5 lb per head daily, cane molasses has an energy value equal to corn when fed to heavy cattle consuming high-grain diets. Higher amounts are not recommended because the value of molasses declines very rapidly.

Liquid protein supplements based on molasses have become very popular in cattle feeding because of economics and ease of feeding. Liquid molasses–urea mixtures are excellent sources of energy and protein which have been shown to

TABLE 10.7

Effects of Liquid Supplement Formulation on the Performance of Beef Cattle Fed Corn Silage-Based Diets[a]

	Molasses urea	Molasses urea/bypass protein
Number of pens	10	10
Gain (kg/day)[b]	1.08	1.13
DM intake (kg/day)	6.86	6.72
Feed:gain[c]	6.33	5.95

[a]Adapted from Willms and Britzman (1994).
[b]Means differ ($p < 0.07$).
[c]Means differ ($p < 0.01$).

consistently improve growth rate and feed intake by cattle fed high-roughage diets. Liquid supplements are also widely used in beef cattle finishing programs in place of dry protein supplements.

Molasses-based liquid supplements which contain a combination of urea and ruminally undegradable protein are now being marketed for beef cattle feeding. Many of these supplements contain animal proteins, such as feathermeal, bloodmeal, or condensed fish solubles. In some situations, there may be an advantage to feeding liquid supplements containing ruminally undegradable protein (Table 10.7). Presumably, feeding supplements that contain ruminally undegradable protein improves the supply of amino acids needed for growth.

B. Beet Molasses

A by-product of the sugar beet industry, beet molasses actually is listed in most feed charts as containing more TDN than cane molasses (79 versus 72% TDN on a dry-matter basis; NRC, 1982). It also contains more crude protein than cane molasses due to certain additives incorporated during processing. Beet molasses and cane molasses contain comparable levels of sugar.

In beet processing, cleaned beets are stripped and sliced and then the soluble sugars are extracted with warm water, leaving wet beet pulp. After the liquid is concentrated by heating and evaporation, sugar crystallizes and is separated mechanically, but considerable sugar remains dissolved. Thus the liquid is treated further with chemicals to remove additional sugar. The final liquid has a sugar level similar to that for cane, or blackstrap, molasses. Beet molasses has essentially the same feeding value as cane molasses for beef cattle, but its tendency to have a laxative effect on cattle should be taken into consideration. The addition of certain alkaline salts and other laxative materials in the manufacturing process

must also be considered. For finishing cattle, beet molasses should be limited to 1 or 2 lb per head daily. With proper management, cattle weighing 700 to 1000 lb may consume 3 to 4 lb of beet molasses per head daily without adverse effects.

C. Condensed Corn Steepwater Solubles

This is produced by evaporation of the water in which corn kernels are soaked or steeped in the early stages of the corn manufacturing process. The steeping operation is comparable to cooking sweet corn in that some soluble material is extracted from the corn, thus clouding the cooking water. This represents small amounts of soluble proteins and carbohydrates. However, when the steep water is concentrated by evaporation, the resulting product has a consistency similar to other molasses products and contains about 10% protein. Quite often this product is less expensive than cane molasses and thus may be incorporated into liquid supplements as a natural protein source. It does not have the palatability of cane molasses, but has a comparable energy value and a superior protein value.

D. Lignin Sulfonates

These and comparable products are made from wood as by-products of the pulping industry. At least 15 different paper manufacturing companies are in operation in the United States and are producing lignin sulfonate products. Chemically, lignin sulfonates are one of a combination of ammonium, calcium, magnesium, or sodium salts of the spent sulfite liquor derived from the sulfite digestion of wood. Wood is reacted under conditions of heat and pressure with sulfur dioxide and the mineral salts. Lignin sulfonates are composed of an indigestible fraction containing lignin and a potentially digestible fraction containing structural and nonstructural carbohydrates. On a TDN basis, lignin sulfonates are considered to have about one-half the energy content as cane molasses. However, because such lignin sulfonates are used primarily as carriers in liquid cattle supplements, it is difficult to demonstrate any performance difference between cattle fed liquid supplements formulated with cane molasses or lignin sulfonates. Lignin sulfonates generally are used as a substitute for one-fourth to one-third of the molasses in liquid cattle supplements.

E. Other Types of Molasses-like Materials

This category includes corn molasses, or hydrol, and citrus molasses. When economics permit, either may be used to replace one-fourth to one-third of the cane molasses in beef cattle liquid supplement formulations without affecting cattle performance.

TABLE 10.8

Estimated Usage (in Millions of Pounds) of Fats in Animal Feeds[a]

	1987		1991	
Type of feed	Yellow grease	Added fat	Yellow grease	Added fat
Swine	160	250	250	300
Beef cattle	95	240	200	250
Dairy cattle	55	100	50	200
Broilers	310	1025	400	1200
Layers	15	30	20	35
Turkeys	120	350	300	500
Dogs	90	365	50	400
Cats	20	75	10	100
Other species (veal)	20	40	25	50
Total	985	2475	1305	3035

[a]Adapted from Bisplinghoff (1991).

III. FAT

Extensive research on fat as a cattle feed has been conducted because of its high energy content. Fat contains 2.25 times as much energy as carbohydrates or proteins. Theoretically, if feed-grade fat is less than 2.25 times as expensive per pound as carbohydrate feeds, it would be worthy of consideration as a feed ingredient. Historically, however, feed fats sell for more than 2.25 times the cost of energy grains. Much research effort has been expended in learning how fat might fit into beef cattle diets.

Historically, fats have been an important component of diets for several species, but perhaps the most critical formulation has been that obtained for broilers wherein high energy diets are very critical and quite difficult to achieve (Table 10.8). Another use of fat is in milk replacers. In some feeding situations, it may be possible to substitute a combination of a high-energy fat and a lower-energy feedstuff for the cereal grain, but this does not occur too often.

Hale (1966) summarized 12 feeding trials in which the addition of 4% fat and 1% dicalcium phosphate was examined. In 11 of the 12 trials, growth rate of cattle was improved an average of 8% by feeding fat. Total feed consumption was only slightly less for cattle fed the fat- and dicalcium phosphate-supplemented diets; therefore, efficiency of feed conversion was about 8% better for such diets.

Although the maximum level at which fats may be added to diets has not been definitely established, a level of 4 or 5% added fat is probably most appropriate. Gramlich and co-workers (1990) reported that for steers finished on a corn-based diet, 4% tallow appeared to be optimum. Higher amounts of tallow resulted in

TABLE 10.9

Performance and Carcass Characteristics of Steers Fed Graded Amounts of Tallow in Corn-Based Diets[a]

	Tallow (% of diet dry matter)				
	0	2	4	6	8
Feed DM intake (lb/day)[b]	23.3	23.7	22.1	21.7	21.5
Gain (lb/day)[c]	3.84	3.88	3.88	3.65	3.33
Gain:feed[d]	0.165	0.164	0.175	0.168	0.155
Ribeye area (inches^2)	13.15	13.41	12.90	13.00	12.73
Backfat (inches)	0.55	0.51	0.51	0.54	0.53
KPH (%)	2.68	2.80	2.68	2.69	2.74
Yield grade	2.86	2.68	2.84	2.84	2.87
Percent choice	80	75	70	68	60

[a]Adapted from Gramlich *et al.* (1990).
[b]Linear ($p < 0.01$).
[c]Linear ($p < 0.001$); quadratic ($p < 0.01$).
[d]Quadratic ($p < 0.03$).

poorer gain and efficiency (Table 10.9) In high-roughage diets containing dry hay or straw or a combination of the two, it is possible to incorporate fat at levels as high as 20% (Hale, 1963).

Feeding steam-rolled barley will result in about 7% faster gains with 11% less feed per pound of gain than will dry- or steam-rolled grain sorghum. However, feeding trials at the University of Arizona demonstrated that the addition of fat to sorghum diets resulted in similar cattle performance relative to barley feeding. Generally, added fat in the diet has resulted in a depression in appetite greater than would be anticipated from the increased energy content of the added fat. The exception to this has been research findings in the southwestern United States where the addition of up to 5% fat to finishing beef cattle diets was practical. Such diets generally are fairly dry from having been steam-flaked and then exposed to the very arid climate. In contrast, in the Corn Belt a great deal of higher moisture feeds, such as corn silage and high moisture grains, is fed.

Research at Purdue (Hatch, 1971) indicated that moisture content of the diet may affect the response to added fat. In contrast to the benefits obtained from adding fat to dry diets (increased gain, improved feed efficiency), the benefits observed in high moisture diets (corn silage, high-moisture corn diets) were minimal (Table 10.10). The addition of 3, 6, or 9% tallow depressed rate of gain and feed consumption so that efficiency of feed conversion improved with tallow feeding. These results tend to agree with research at other experiment stations in which the feeding value of added fat is questionable for diets containing high-moisture feeds such as corn silage and high-moisture grains.

TABLE 10.10

Performance of Steers Fed Graded Amounts of Fat in High-Moisture Diets (233-Day Feeding Period)[a]

	Amount of added fat (%)			
	0	3	6	9
Feed intake (lb/day)	15.9	14.5	14.2	14.2
Gain (lb/day)	2.22	2.00	1.98	1.96
Feed:gain	7.2	6.6	6.5	6.5

[a]Hatch (1971).

IV. MISCELLANEOUS ENERGY CONCENTRATES

These are manyfold and will be mentioned only briefly. For example, "tailings," a dusty by-product of grain cleaning, is an excellent cattle feed when its dusty characteristics are masked in a slurry feeding system. Wheat flour which had become damp in railroad cars, and thus unfit for human consumption, is an excellent cattle feed when mixed into a slurry. Peanut butter, stale cake mixes, stale bread, broken cookies, stale candy bars, and almost any material which (1) is reasonably digestible by cattle, (2) does not contain toxic materials, (3) is not extremely unpalatable, (4) does not contain too much crude fiber, and (5) is economical probably can be formulated and balanced into cattle feeding programs. Any "different" or unique feedstuff which meets the five qualifications indicated above probably should be investigated and evaluated as a potential cattle feed. For an excellent overview of by-product feeding, the reader is referred to Rust (1991).

V. PROTEIN CONCENTRATES

In formulating diets for beef cattle, a portion of the protein allowance can be satisfied by feeding nonprotein nitrogen, such as urea. However, natural or true proteins are used a great deal in diet formulation. Nutritionists generally agree that urea should generally not supply more than one-third of the total protein of the diet (see Chapter 4 for further discussion on the use of urea). Furthermore, in times of stress, true protein should probably be used in diet formulation. For example, newly weaned calves, shipped for many miles and unloaded at their feedlot destination, should probably receive diets containing true protein supplements. Very young cattle (less than 8 to 12 weeks old) have poorly developed

rumens with low populations of microorganisms and consequently do not utilize nonprotein nitrogen well. Thus, the supplemental protein should be provided by a true protein source.

Supplemental protein can be provided by a wide variety of protein sources. These can broadly be divided into vegetable protein sources and animal proteins. Vegetable proteins include the oilseed meals and by-products of commodity processing (e.g., corn gluten meal, distiller's grains). The majority of animal proteins are by-products of the animal processing industry. The most commonly used of these protein feeds will be discussed.

A. Cottonseed Meal

Cottonseed meal is a by-product of the cotton crop. After removal of the fibrous lint, the cotton seeds are broken open, allowing the seed kernel to drop out; subsequent vibration techniques separate out the seed kernel. Crushing of the seed kernel follows and oil is removed either by hydraulic pressure or extraction. After as much oil as possible has been removed, the remaining product, cottonseed meal or cake, is ready for processing as livestock feed. The use of the hydraulic method of "squeezing" out the oil results in rather large residual pieces called "cake," which can then be ground into "meal." The cake has always been popular with cattle feeders who feed out-of-doors, because it is not apt to blow away.

Because cottonseed meal is a by-product feedstuff, it is possible to have widely varying qualities of meals between batches. Much of this variation can be attributed to the amount of cottonseed hull included in the meal. It is important that formulators and feeders study feed tags carefully to evaluate the potential feeding value of cottonseed meal. Knowledge of the protein content is helpful because as the fiber content increases in a feedstuff (i.e., as with added hulls), concentration of other ingredients decreases.

Cottonseed meal usually contains about 41% crude protein and 12 to 13% crude fiber. It contains nearly 1% phosphorus, but is quite low in calcium (0.15%). Unless specially processed, cottonseed meal contains levels of gossypol which can be harmful to monogastric animals. However, this is not a problem for beef cattle with well-developed ruminal function (greater than 350 to 400 lb liveweight) because the ruminal microbes can detoxify gossypol.

Cottonseed meal has a tendency to firm up the excreta, so it is an excellent protein supplement for diets which tend to be laxative in nature, as is the case for high corn diets, especially those based upon high-moisture corn.

Sometimes, though not often, cottonseed meal may be more economical per pound than corn, especially at locations in proximity to cotton processing plants. When it is fed at an amount in excess of what is needed to meet animal protein

allowances, its energy value is slightly less per pound than corn. Thus, as a general rule, it is not good husbandry to feed more than is actually needed to meet protein requirements.

B. Soybeans and Soybean Meal

In the United States, soybeans have become an outstanding cash crop. The harvested bean is seldom used intact, but rather the oil and residual meal are separated for economic reasons. There is no nutritional reason why full-fat soybeans cannot be fed to beef cattle. However, it is seldom justifiable from an economic standpoint. On the other hand, many dairy producers feed roasted or raw full-fat soybeans to lactating dairy cows with good results. Full-fat beans should be rolled, cracked, or ground before feeding for maximum utilization.

Solvent-extracted soybean meal containing 44 or 48% crude protein (dry-matter basis) is often used as a source of supplemental protein for beef cattle. It is an outstanding source of true protein and is quite palatable for cattle. Therefore, it is commonly the protein of choice when natural protein is desired. There are no special precautions about its use in cattle rations. Because of its excellent balance of essential amino acids, when mixed with corn, monogastric feed formulations utilize soybean meal extensively for a source of supplemental protein.

Soybean meal protein is extensively degraded in the rumen, so that while the balance of amino acids is quite good, only a fraction of the amino acids reach the small intestine. Various processing methods have been developed to reduce ruminal degradability of soybean protein. These include the application of heat or chemical treatments or a combination of the two. In some situations, feeding specially processed soybean meal with greater ruminal escape protein content can improve the growth rate of cattle compared with feeding solvent-extracted, or low ruminal escape, soybean meal (Hancock *et al.*, 1994). These products are likely more efficacious in diets containing low to moderate amounts of metabolizable energy, such as diets based on corn silage, compared with high energy concentrate diets (e.g., finishing diets containing 80% corn).

C. Canola Meal

Canola meal is a rapeseed cultivar that was created by Canadian scientists in the 1970s. In contrast to rapeseed, canola is low in glucosinolates, which are goitrogenic when ingested in large amounts by cattle. Canola oil accounts for a substantial proportion of global vegetable oil production, ranking only behind soybean oil and palm kernel oil.

Canola meal contains about 40 to 46% crude protein on a dry-matter basis, and has a slightly lower energy content than soybean meal. In growing and finishing diets, canola meal can be used as a substitute for cottonseed meal or

soybean meal. Zinn (1993) demonstrated that the ruminal escape protein content of canola meal is slightly greater than that of soybean meal and that, on an isonitrogenous basis, canola meal may supply greater quantities of methionine (an essential amino acid) to the small intestine compared with soybean meal.

D. Linseed Meal

A by-product of the linen and linseed oil industry, linseed meal is derived from flaxseed and was the number one choice as supplemental protein for beef cattle formulations for many decades. Haircoats of cattle fed supplemental linseed meal always had a superior gloss or sheen, compared to cattle fed other sources of supplemental protein. Linseed meal does have a laxative effect on cattle.

Linseed meal usually contains 32 to 34% crude protein; therefore, one must feed more linseed meal compared with cottonseed meal or soybean meal to supply a given amount of protein. Linseed meal is produced in the cooler northern part of the United States and thus transportation costs plus scarcity often make it more expensive per unit of protein than other sources.

E. Commodity By-Products

By-products considered in this class include corn gluten feed, corn gluten meal, distiller's grains with solubles, and brewer's grains. Corn gluten feed and corn gluten meal are by-products of the wet milling of corn. Corn gluten feed consists of bran and steep liquor which are usually combined in a ratio of two parts bran to one part steep liquor. It may contain some corn germ. Corn gluten feed has about one-half the protein content of soybean meal and is low in ruminal escape protein. Corn gluten meal is a high-protein, high-energy ingredient composed of corn protein (zein) and small quantities of starch and fiber. Gluten meal contains about 55 to 65% protein (dry-matter basis) of which a large proportion escapes ruminal fermentation. Corn gluten meal is an excellent source of sulfur amino acids (methionine) but is a relatively poor source of lysine.

Brewer's grains are the spent grains remaining from beer making. These grains may be fed in either the wet (80% moisture) or dry (10% moisture) form, with the wet form having slightly greater energy content for ruminants. On a dry-matter basis, brewer's grains contain about 22 to 28% crude protein. The amino acid balance of brewer's grains is quite good relative to requirements of growing cattle. Because brewer's grains are low in sodium and potassium compared with oilseed meal, special consideration should be given to supplementing these minerals when brewer's grains are used in place of oilseed supplements.

Distiller's grains are by-products of the alcohol industry and typically consist of corn, grain sorghum, rye, barley, or a combination of these grains. The

composition of distiller's grains is dependent upon the type of grain used, grain quality, fermentation conditions, drying conditions, and the quantity of solubles blended into the fibrous portion of the grain. Distillers grains typically contain about 23 to 30% crude protein (dry-matter basis) and 86 to 88% TDN. Distiller's grains are high in ruminal escape protein compared with solvent extracted oilseed meals.

F. Animal Proteins

Proteins of animal origin are derived from meat and poultry processing, from milk processing, and from fish and marine products processing. The value of animal proteins for ruminants is based primarily on the intestinally available protein content of these sources. Because animal proteins generally have high amounts of ruminally undegradable protein, they should be used to supply amino acids that complement the amino acids supplied to the animal by the ruminal microbes. Consequently, one should consider the balance of amino acids found in animal proteins when they are used in diet formulations. Several animal proteins that are typically fed in ruminant rations are discussed below.

1. Blood Meal

Blood meal is high in protein (90% protein, dry-matter basis) and high in ruminally undegradable protein. Blood meal is prepared by any one of three processes: (1) spray drying, (2) cooker drying, and (3) flash drying. Whereas blood meal is an excellent source of bypass protein, it is low in the essential amino acid isoleucine. Blood meal is not palatable and its use in growing and finishing diets should be limited to less than 3 to 5% of the diet on a dry-matter basis. It is relatively low in both calcium and phosphorus.

2. Meat and Bone Meal

Meat meal and meat and bone meal are the dry rendered products from mammalian tissues excluding hair, hoof, horn, and hide trimmings. Meat and bone meal contains about 45 to 50% crude protein and is high in calcium and phosphorus. About 60% of the protein in meat and bone meal escapes ruminal degradation, but there is concern in the feed industry regarding the amount of batch-to-batch variation in escape protein content of rendered animal products. Meat and bone meal should be limited to 10% or less of the diet on a dry matter basis when fed to growing and finishing catte.

3. Fish Meal

Fish meal is manufactured from clean, dried, ground tissues of undecomposed whole fish, or fish cuttings. Over 90% of the fish meal produced in the United States is made from menhaden, which is a high-oil fish unsuitable for human

consumption. Fish meal contains about 65% protein, on a dry matter basis, of which about 60 to 80% escapes ruminal degradation. Fish meal has an excellent profile of amino acids compared with estimated requirements for growth and milk production by ruminants. Fish meal is high in calcium (3 to 6%) and phosphorus (1.5 to 3.0%) and relatively high in oil (10%). The high oil content is of concern because unsaturated oils, such as fish oil, may have detrimental effects on ruminal function. Because of this, and because of palatability concerns, fish meal should compose less than 5% of the diet (dry-matter basis). Recently, a special grade of fish meal having higher ruminal escape protein content has been developed. Several researchers have reported superior performance by growing cattle fed ruminant-grade fish meal compared with other animal (feather meal) or vegetable proteins (cottonseed meal). Improved performance is likely related to an improved supply of digestible amino acids when diets contain fish meal.

4. Poultry Feather Meal

Hydrolyzed feather meal is defined as the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry. Feather meal is high in protein (85 to 90% protein on a dry-matter basis) but its use in monogastric diets is limited because it has a poor balance of amino acids. It is particularly low in lysine, an essential amino acid for growth and milk production. When moderate energy diets are formulated with feather meal as the sole source of supplemental protein, growth and efficiency of cattle are generally poor. However, feeding feather meal in combination with blood meal markedly improved performance of cattle in work conducted by researchers in Nebraska (Table 10.11). Ostensibly, the pattern of amino acids supplied to the animal is improved when feather meal is fed in combination with other proteins, thus resulting in improved growth rate or efficiency of protein utilization. A particular concern regarding feather meal is batch variation relative to estimated digestibility in the small intestine (Howie *et al.*, 1994).

G. Animal Wastes

1. Dehydrated Poultry Waste (DPW)

The chemical composition of this product varies greatly and is related to length of storage in the wet form before processing. The greatest variation is in crude protein content because of ammonia losses in wet manure stored for long periods. However, the average nutrient content for DPW is 10% moisture, 30% crude protein, and 12% crude fiber, which then categorizes DPW as a bulky protein concentrate.

It has a digestible energy value of 2000 kcal per kilogram for cattle, making it equal to good-quality hay. The TDN content is about 53%. However, DPW is not

TABLE 10.11

Effects of Feeding Combinations of Feather Meal(Fth) and Blood Meal (BM) on Performance of Calves[a]

	No. of calves	Initial wt (kg)	Gain (kg/day)	DMI (% of BW)	Protein intake (% of BW)
Trial 1					
Urea	9	215	0.38	2.11	0.00
100% Fth	9	213	0.48	2.13	0.11
87.5 Fth:12.5 BM	8	218	0.52	2.12	0.11
75 Fth:25 BM	8	219	0.61	2.16	0.11
50 Fth:50 BM	9	212	0.56	2.17	0.11
100% BM	10	215	0.63	2.13	0.11
Standard error	—	6	0.04	0.07	0.01
Trial 2					
Urea	10	235	0.38	2.20	0.00
100% Fth	10	236	0.48	2.19	0.13
87.5 Fth:12.5 BM	10	240	0.62	2.22	0.13
75 Fth:25 BM	9	238	0.55	2.21	0.13
50 Fth:50 BM	9	235	0.58	2.23	0.13
100% BM	10	237	0.68	2.22	0.13
Standard error	—	6	0.04	0.06	0.01

[a]Adapted from Blasi *et al.* (1991).

normally fed as an energy source, but rather is used as a source of crude protein, practically all of which is NPN. The crude protein digestibility of DPW for ruminants is quite low, probably in the range of 50%.

2. Broiler Litter

Many factors contribute to a wide range of nutrient values given to broiler litter, particularly the type and quantity of litter used. Broiler litter is valued mainly for its nitrogen content; the average crude protein content is 30% on a dry-matter basis. Usually it contains about 15% crude fiber which tends to be highly lignified. Litter also is quite high in ash (15%). About one-half of the protein fraction is made up of true protein that is high in glycine but low in arginine, lysine, methionine, and cystine. Uric acid constitutes about one-half the total NPN. The digestible energy content is about 2440 kcal per kilogram, making it comparable to alfalfa hay in ruminant rations.

Broiler litter is rather unacceptable to beef cattle and, if they have the opportunity to choose, cattle will practically ignore diets containing this product (Fontenot *et al.*, 1971). In a research trial, steers were fed diets containing 0, 25, or 50% dried broiler waste (Table 10.12). Despite their apparent dislike for diets containing broiler material, statistical analysis failed to show significant depression in gain of cattle fed diets containing 25% of the material.

TABLE 10.12

Performance of Cattle Fed Broiler Litter[a]

	Amount of added litter (%)		
	3	6	9
Initial weight (lb)	816	831	822
Gain (lb/day)			
Days 1 to 50	1.84[b]	1.54[b]	0.50[c]
Days 51 to 121	1.43	1.40	1.03
Days 1 to 121	1.60	1.47	0.81
Feed intake (lb/day)			
Days 1 to 50	21.9[b]	19.2[b]	13.8[c]
Days 51 to 121	20.3	20.4	17.2
Days 1 to 121	21.0	19.8	15.8

Note. Means in the same row with unlike superscripts are different ($p < 0.05$).

[a]Fontenot *et al.* (1971).

3. Dry Cattle Feedlot Waste

Three trials were conducted in Texas (Albin and Sherrod, 1975) where cattle feedlot waste dries quickly due to the low humidity. In one trial, waste which had been scraped and stockpiled for a month was ground and included at concentrations of 0, 20, 40, or 60% of the diet in a high-energy, protein-adequate diet. In trial II, the manure was composted for 5 days by bringing the moisture content up to 40%. The third trial consisted of adding unaltered feedlot waste to a low-energy, low-protein diet resembling a high-roughage diet. In all three trials, as the percentage of feedlot waste increased, apparent digestibility of all nutrients decreased. However, apparent digestibility coefficients for feedlot waste were higher when it was included in low-energy, low-protein diets, indicating that its use is limited primarily to such diets and that it has only small replacement value in high-energy diets. Composting feedlot waste lowered the digestibility of organic matter and protein, whereas cell wall digestibility increased.

4. Cattle Manure Wastelage

Perhaps the most common-sense approach to feeding manure is to ensile it with a lower grade roughage such as stalks, cobs, straw, or nonlegume hay on an approximately 50/50 w/w basis. In other words, 50 lb of wet cattle feedlot waste is combined with 50 lb of a drier material such as hay or straw and then ensiled. Anthony (1971) used such a product (57 parts wet manure to 43 parts grass hay, ensiled) in cattle feeding research (Table 10.13). Manure feeding reduced the amount of basal feed required per unit of gain without reducing rate of gain by cattle. Substitution of straight shelled corn (treatment 3) or of corn plus cotton-

TABLE 10.13

Performance of Cattle Fed Manure Wastelage[a]

	Treatment number			
	1	2	3	4
Diet composition (% of DM)				
Basal[b]	100	60		
Cattle wastelage			40	40
Corn			60	60
Manure		40		
Cottonseed meal (lb/day)				2
Initial weight (lb)	627	623	627	625
Gain (lb/day)	2.68	2.62	2.70	2.90

[a]Anthony (1971).
[b]Corn, 75; cottonseed meal, 8; dehydrated alfalfa, 5; molasses, 10; salt, 1; defluorinated phosphate, 1; vitamin A also included.

seed meal (treatment 4) for the basal diet supplemented with wastelage further improved efficiency of gain.

VI. SUMMARY AND CONCLUSIONS

There are numerous grains and by-product feeds that can be economically fed to beef cattle if proper attention is given to processing and feeding management. In many cases some products (i.e., screenings) are quite variable in nutrient content and feeding value from batch to batch. To minimize the risk of reducing animal performance due to variation in nutrients and quality, these materials should be used as only part of the ration. Care should be taken to properly supplement diets containing substitute feeds. In some cases, it may be advisable to provide higher than normal levels of supplemental minerals, vitamins, and protein. This provides a wide margin of safety when it is recognized that a particular feedstuff is quite variable in quality from batch to batch.

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III

The Breeding Herd

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11

Breeding Herd Nutrition and Management

Tilden Wayne Perry

The real objectives in feeding the beef breeding cow herd are (1) to produce a 90%-plus calf crop of healthy heavy calves at weaning time at a reasonable cost, and (2) to have the brood cows, bred at 2 months postpartum, in sufficiently vigorous condition for each cow to continue to produce one calf every 365 days.

It is not difficult to meet the nutritional needs of the mature nonlactating beef cow, whether or not she is pregnant. Naturally, she does have definite nutritional requirements which must be met, or impaired reproductive performance may be expected. Principal among her nutrient requirements which may require special attention include at least limited energy, protein, vitamin A, calcium, phosphorus, sodium and chlorine. Almost all of her other nutrient requirements will be met adequately unless she is on a starvation diet. In certain circumstances, trace mineral deficiencies may be manifested. These include magnesium, copper, cobalt, and selenium. The National Research Council Bulletin on Beef Cattle Nutrient Requirements (1984) has established requirements for protein, energy, calcium, phosphorus, and vitamins A and D, plus a few trace minerals (see Appendix IV).

Lactating dietary requirements differ from nonlactating ones in required higher levels of energy, nearly doubled levels of protein, calcium, and phosphorus, but no change in vitamin A. Reproduction in mature beef cattle generally is a natural phenomenon requiring only slightly elevated quantities of nutrients, except as listed above. Often in more pampered cow herds, it is a matter of overfeeding of energy—and possibly protein and other nutrients—rather than underfeeding. A prime example of overfeeding may occur in show herds and in sale cattle which have been fitted too highly.

I. NUTRITIONAL NEEDS OF REPLACEMENT HEIFERS

Quantitatively, the greatest need for nutrients in developing replacement heifers is energy, followed by protein. One of the most complete studies to

demonstrate such effects is that of Wiltbank *et al.*, (1969), in which the interactive levels of energy and protein for weanling heifers at the age of puberty—or the first appearance of estrus—were studied. Two levels of feeding were compared. Heifers on the "high" nutritional level were fed a full feed of concentrates plus hay whereas heifers on the "low" nutritional level were fed only protein supplement and hay. Heifers were fed the respective high- and low-energy diets from weaning until time of first ovulatory estrus (which was defined as puberty). Estrus was detected with the aid of sterilized bulls which had a marking grease pigment on their briskets. The effect of energy level on age at first estrus for developing heifers is quite obvious (shown in Table 11.1). The average age at puberty was 381 days for heifers on a high nutritional level of energy for both straightbred and crossbred heifers; on a low level of nutrition, puberty did not occur until 572 days of age for straightbred heifers and 424 days for crossbred heifers, respectively. Average live weight at puberty was 299 and 330 kg for straightbred and crossbred heifers, respectively, on high nutrition, and 268 and 254 kg, respectively, on low nutrition. Wiley *et al.* (1991), in a slightly different design, fed first calf heifers either a low-energy protein diet or a maintenance prepartum diet; although the maintenance-fed heifers weighed 50 kg more precalving (482 vs 432 kg), calf birth weights (32 kg) and weaning weights (230 vs 225 kg) were similar. However, second calving performance data were not presented.

The data in Table 11.1 bear out the generally accepted idea that differences exist among breeds in their age of reaching puberty, with Herefords perhaps taking a bit longer. However, the data presented demonstrate that nutrition probably has a much greater effect than breed on age at puberty.

TABLE 11.1

Age and Weight of Beef Heifers at Puberty as Affected by Energy Level Fed[a]

		Hereford (H) or Angus (A)					
	Bull:	H	A	A	H		
	Cow:	H	A	H	A	Straight-bred	Cross-bred
Puberty age (days)							
High nutrition		387	374	384	378	381	381
Low nutrition		660	483	416	402	572	424
Difference		273	109	62	24	191	43
Puberty weight (kg)							
High nutrition		293	305	331	329	299	330
Low nutrition		279	257	270	238	268	254
Difference		14	48	61	91	31	76

[a]Wiltbank *et al.* (1969).

Once puberty, ovulation, estrus, and fertilization have been achieved in the young heifer, consideration must then be given to her nutrition and management for the next 283 days of gestation.

The USDA (Wiltbank *et al.*, 1965) studied the effect of energy and protein levels in the diet of pregnant heifers on reproductive performance of heifers carrying their first calves. In the comparison of three energy levels heifers on high energy were fed *ad lib* (25% timothy hay, 10% molasses, plus corn and cob meal and cottonseed meal to meet supplemental protein requirements); heifers on medium energy were fed 66% as much as that consumed by the high-energy heifers; those on the low energy level were fed only enough to maintain body weight. Then within each of the three energy levels, protein was fed at high (230 g digestible protein per 100 kg body weight), medium (150 g digestible protein per 100 kg body weight), and low (60 g digestible protein per 100 kg body weight) levels.

The heifers were kept on their respective diets through gestation, except that the heifers on low energy were fed slightly more to compensate for their increase in weight due to pregnancy. This program continued for 180 days or until they were 90 days pregnant with their second calf. Beginning at this time, heifers were fed *ad lib* on a diet of 94% timothy hay and 6% cottonseed meal, plus vitamin A and minerals, through their second calving. This diet then tended to improve the condition of the low-energy heifers and to reduce the obesity of the high-energy group (Table 11.2).

A large number of the calves born to heifers on the high-energy–low-energy protein regimen or on the high-energy–medium-energy protein regimen died, either at birth or shortly thereafter. Many of such calves were presented for birth backward or in some other abnormal position. Birth weights of calves born to heifers on high-energy diets were not excessive and the gestation period was comparable. Calving difficulty of heifers appeared to be related more closely to their own conditions rather than to the size of the calf. Birth weights of calves born to heifers on the low-energy diets were consistently and considerably lower than those of calves born to heifers on high- or medium-energy diets which contained high or medium protein levels.

Heifers fed high-energy or medium-energy diets with either high or medium protein levels produced the most milk and thus heavier calves at 60 days of age. Low protein in the dam's diet caused decreased milk production and thus lowered 60-day calf weights. It is interesting to note from Table 11.3 that on low energy diets, a high level of protein seemed to depress milk production of the dam and growth of the calf. In the past, we have suggested that if the energy is low, it is best not to feed higher levels of protein to the dam. However, with the demonstration by this author (Perry, 1988) that beef cattle respond to rumen bypass protein, there may be a different interpretation in protein feeding, whereby bypass protein is considered. Rusche *et al.* (1993) fed two levels of protein (100

TABLE 11.2

Gestation Energy and Protein Level in First Calf Heifer Diets, and Reproductive Performance[a]

Dietary level	Heifer wt 1 week before calving (kg)	Live calves (%) At birth	Live calves (%) At 2 weeks	Live calves (%) At wean	Average birth wt (kg)	Calf's birth wt (% of dam's wt)	Average gestation period (days)
High energy							
High protein	523	80	20	20	25	5.1	277
Medium protein	495	80	40	40	31	6.3	275
Low protein	397	67	50	50	21	4.9	277
Average	472	76	37	37	26	5.4	276
Medium energy							
High protein	421	100	100	100	27	7.2	272
Medium protein	405	80	80	80	25	6.8	274
Low protein	345	80	80	80	25	8.1	282
Average	390	87	87	87	26	7.4	276
Low energy							
High protein	284	75	75	75	20	8.3	280
Medium protein	259	100	100	100	18	8.3	274
Low protein	242	67	67	67	19	8.8	273
Average	261	81	81	81	19	8.5	276
Protein level effect (average, all energy levels)							
High protein	409	85	65	65	24	6.8	276
Medium protein	380	86	73	73	25	7.1	274
Low protein	328	71	66	66	22	7.3	277

[a]Wiltbank *et al.* (1965).

or 150% NRC) and two types of protein [soybean meal (low bypass) or corn gluten meal/blood meal (high bypass)] to 364-kg primiparous 2-year-old heifers. Milk yield was increased by the feeding of bypass protein (5.17 vs 4.72 kg/day on 100% NRC protein; 5.90 vs 5.10 kg/day on 150% NRC protein). Naturally the increased milk production resulted in faster gains of the calves through the first 90 days. However, by weaning time, much of the difference due to source and amount of protein had disappeared.

Note in Table 11.3 the effect of energy and protein on milk production and thus calf weights in the USDA (Wiltbank *et al.*, 1965) study.

Additional energy and protein will cause brood cows to gain more rapidly during pregnancy and thus, even though they produce more milk, they will complete the lactation phase at a heavier weight. On the other hand, if postlactation feeding is good, such as on good pasture, lighter cows will tend to gain back the lactation weight they may have lost.

From the previous discussion, it is obvious that the nutrient requirements of

TABLE 11.3

Growth of First Calves and Milk Production of Heifers as Affected by Energy and Protein Levels[a]

Dietary level	Weight gain of calves, first 60 days (kg)	12 hr. milk production of dams at 60 days (kg)
High energy		
High protein[b]	47	3.7
Medium protein	42	3.3
Low protein	26	2.8
Average	38	3.3
Medium energy		
High protein	40	3.4
Medium protein	45	3.8
Low protein	22	3.0
Average	36	3.4
Low energy		
High protein	17	1.5
Medium protein	19	2.0
Low protein	18	2.1
Average	18	1.9

[a]Wiltbank *et al.* (1965).

[b]Average protein effect, (a) weight of gain calves at 60 days, high, 35 kg; medium, 35 kg; low, 22 kg; (b) milk production at 60 days, high, 2.9 kg; medium, 3.5 kg; low, 2.6 kg.

the replacement heifer from weaning through her first pregnancy and lactation are quite specific and should be adhered to if optimum performance is to be obtained (Fig. 11.1). It is fortunate, however, that even if her nutrient requirements are not met—or even if they are oversupplied, as in the case of energy—probably no permanent damage has been done. Therefore, she will be capable of performing quite normally in her second and subsequent pregnancies and lactations if she is given the opportunity with reasonably sound feeding practices during these subsequent pregnancies. Possibly no other farm animal is as capable of living a normal, healthy reproductive life as the beef female.

A replacement heifer should gain 0.5 kg per day, or slightly more, from a weaning weight of 200 to 225 kg through her first pregnancy. This means that if she calves shortly after she is 2 years of age, she should weigh near 400 kg for most of the English breeds, and a bit more for the heavier breeds. It is not too difficult to supply enough feed to cause 0.5-kg per day gain, but attention should be given to some details. The National Research Council (see Appendix IV) suggests that a 200-kg heifer (weanling) gaining 0.5 kg per day should receive 0.56 kg crude protein, 3.5 kg TDN, 14 g calcium, 13 g phosphorus, and 13,000 IU of vitamin A per head, daily. Furthermore, she has a feed capacity for about

Fig. 11.1 Yearling replacement heifers are fed a high silage ration during winter drylot conditions.

6 kg dry matter (6.9 kg of 87% dry matter equivalent). Thus, 6.9 kg of a diet containing 13% dry matter, 8.5% crude protein, 51% TDN, plus calcium, phosphorus, and vitamin A, would meet these requirements. Typically, good pasture or reasonably good quality hay would meet these nutrient requirements, with the possible exception of vitamin A. However, injectable vitamin A may be purchased, and one intramuscular injection of 5 million IU of vitamin A per heifer would suffice for 6 to 9 months.

Some sample feeding programs for weanling heifers from weaning (200 kg and 6 months of age) to breeding time (335 kg and 15 to 16 months of age) follow below.

1. Good quality pasture plus limited protein supplement (0.5 kg per head daily) of a 32% protein supplement, or of soybean meal, or of dehydrated alfalfa pellets if the pasture is fairly mature. A free-choice lick tank containing a 32% protein liquid supplement would work well here, also. If the pasture herbage is in

short supply, then 1 kg of grain plus the protein supplement will be needed. A free choice mineral mixture consisting of two parts dicalcium phosphate to one part of trace mineralized salt should be available in a device which will prevent rain from getting to the mineral mixture.

2. In the season when pasture is not available, bright clean hay containing a small amount of legume will be satisfactory. However, if the hay is of poor quality, then the grain and protein supplementation listed above should be provided. The free choice mineral mixture listed above should be provided.

3. Corn silage fed on a limited basis (11 kg per head daily) plus 0.7 kg of a 32% protein supplement will cause a gain in excess of 0.5 kg per day—possibly 0.7 kg per day. If this program is followed, the free choice mineral supplement should be included.

4. Alfalfa haylage and small grain haylage are excellent growing feeds for weanling heifers through the time of breeding. Good alfalfa haylage is almost a complete diet in itself and needs little else except free choice minerals.

5. Such by-products as corn stover, cornstalk fields, and straw are low-energy feeds and do not work very well for young heifers. Such products are extremely low in protein, calcium, phosphorus, and vitamin A—as well as energy. Such products should be utilized for the mature beef cow, who is better able to utilize such feeds and whose nutrient requirements are not nearly as exacting as those of the developing heifer.

II. BEEF COW FEEDING PROGRAMS

The nutrient requirements for beef brood cows can be classified under four general headings, namely (1) energy, (2) protein, (3) minerals, and (4) vitamins. These requirements are shown in Table 11.4.

Two major considerations help determine the nutritional requirements of a dry pregnant beef cow or of a lactating beef cow. These are size of the cow and amount of milk produced. The National Research Council (1984) establishes the requirements for most given situations. For example, a 550-kg mature pregnant cow (not in lactation) during the middle third of pregnancy should consume a minimum of 9.5 kg of feed which contains 5.4 kg of TDN, 657 g crude protein, 18 g each of calcium and phosphorus, and 29,000 IU of vitamin A, daily. What kind of diet then are we talking about? It is about 57% TDN and 7% protein, plus calcium, phosphorus, and vitamin A. Almost any kind of high-quality bright hay would meet these requirements. For example, grass hay contains 58% TDN, 12% protein, 0.70% calcium, and 0.25% phosphorus. Thus, good quality grass hay, along with a free choice mineral, should meet nearly all of these nutrient requirements.

Even though it is not difficult to meet the nutrient needs of the pregnant

TABLE 11.4

Nutrient Requirements of Mature Beef Cows[a]

Body wt (kg)	Feed, dry matter per day (kg)	Protein (g)	TDN (kg)	Calcium (g)	Phosphorus (g)	Vitamin A (IU x 1000)
Dry pregnant mature cows, middle third of pregnancy						
350	6.8	476	3.3	12	12	19
450	8.2	570	4.0	15	15	23
550	9.5	657	4.6	18	18	27
650	10.7	739	5.2	22	22	30
Dry pregnant mature cows, last third of pregnancy						
350	7.4	609	4.1	20	15	21
450	8.9	703	4.8	23	18	24
550	10.2	790	5.4	26	21	29
650	11.3	872	6.0	30	25	32
Cows nursing calves, average milk production (5 kg milk/day), first 3 to 4 months						
350	7.7	814	4.6	33	18	30
450	9.2	911	5.3	26	21	36
450	10.5	1001	5.9	29	24	41
550	11.9	1086	6.6	33	27	46
Cows nursing calves, superior milk production (10 kg/day), first 3 to 4 months						
350	6.2	1099	5.1	36	24	24
450	9.1	1186	6.4	39	26	35
550	10.9	1299	7.1	42	30	42
650	12.4	1394	7.8	45	35	48

[a]An adaptation of Table 7 from National Research Council (1984).

mature beef cow, consideration needs to be given to her nutrient needs and how improper levels will affect her performance.

A. Energy

An in-depth study on the effect of energy levels on reproductive performance of mature beef cows was conducted by Houghton *et al.* (1990). In this study, Charolais-Angus rotational cross mature beef cows were utilized. Evaluations of energy level effects included pre- and postpartum energy intake, body condition, dystocia (calving difficulty), suckling status of the dam, and length of time to rebreeding. In this energy level gestation study, diets were formulated to meet NRC (1984) requirements (Table 11.4), adjusted for winter temperature in Indiana, for protein, minerals, and vitamins; only energy level was studied. Energy levels were set at (1) maintenance (100% NRC) or (2) to force cows to lose weight (70% NRC), during gestation, and (1) to gain weight (130% NRC), or (2) to lose weight (70% NRC), during lactation. This study was conducted in drylot.

Energy levels were achieved by altering the levels of ground corn cobs, shelled corn and corn silage in the diet. Dietary energy intake by the cow, either prepartum or postpartum, significantly ($p < 0.05$) affected calf performance. Low energy prepartum diets (70% NRC) resulted in lighter calves at birth (Table 11.5) and at 105 days of age compared to cows fed 100% of maintenance energy.

TABLE 11.5

Effect of Prepartum and Postpartum Cow Energy Levels on Cow and Calf Performance[a]

	Prepartum energy		
	70% NRC (low)	100% NRC (maint.)	Difference
A. Effect of prepartum energy intake on calf weights			
Age of calf	Weight of calves (kg)		
Birth	34.7	39.0	4.3[b]
105 days	127.9	144.6	16.7[b]
205 days	205.5	220.7	15.2
B. Pre- and postpartum energy intake effect on weaning weight			
Postpartum diet	Weight of calves (kg)		
70% NRC (low)	185.7[c]	201.9[c,d]	16.2
130% NRC (gain)	206.7[c,d]	218.9[d]	12.2
Difference	21.0	17.0	
C. Pre- and postpartum energy effect on postpartum cycling cow activity within 60 days postpartum			
Postpartum diet	Cows cycling (kg)		
70% NRC (low)	33.3[c]	52.9[c,d]	19.6
130% NRC (gain)	56.3[d]	54.3[c,d]	3.0
D. Pre- and postpartum energy level effect on postpartum interval to pregnancy			
Postpartum diet	Postpartum interval to pregnancy (days)		
70% NRC (low)	72.6[c]	65.7[c]	6.9
130% NRC (gain)	54.3[d]	68.4[c]	14.1

[a]Houghton *et al.* (1990).
[b]Means in same row differ ($p < 0.05$).
[c,d]Means with unlike superscripts differ ($p < 0.05$).

Postpartum energy intake affected weight gains in the same direction, resulting in an increase in 105-day calf weight of 15 kg. Cow body condition at parturition contributed to length of postpartum anestrous interval, with thin cows (low energy during gestation) having a 28- to 56-day longer interval to first estrus than moderate to fleshy cows; in contrast, overconditioned cows at breeding exhibited a decrease in first service conception rate of nearly 30% compared to cows with slightly less body condition. Higher pregnancy rates of 22 to 29% were shown by cows moving toward or maintaining average body conditions from parturition to conception than for cows that were moving away from average body conditions. Even though these results indicate the desirability of manipulating the energy levels fed from conception to succeeding conception, economic factors must be considered in making such decisions.

Randell (1990) summarized 85 refereed journal articles on the effect of nutrition during pregnancy and concluded adequate energy for suckling beef cows and heifers increased pregnancy rate about 25% or more. Richards *et al.* (1986) concluded body condition at calving—neither too high nor too low condition—was the most important factor influencing early return to estrus and pregnancy. Short and Adams (1988) proposed that decreased available energy is the most common problem in beef cattle reproduction and will result in delayed puberty of young heifers and lengthen postpartum anestrus. They suggested glucose as the specific energy source through which this condition is manifested. Rutter and Randell (1984) suggested pregnant females maintaining bodyweight postpartum have enhanced pituitary function and, thus, reproductive function, based on blood levels of luteinizing hormone.

B. Protein

Meeting the quantitative protein requirements (% of dietary dry matter) for pregnant mature beef cows is not too difficult because of the small quantity required. During the last two-thirds of pregnancy, mature cows require 7 to 8% protein (Table 11.4, 550-kg cow consuming 10.2 kg dry matter and requiring 790 g protein needs 7.75% protein in her dietary dry matter). Naturally growing first-calf heifers will require a bit more protein—up to 9.5% protein. Also, during lactation, both heifers and mature cows require more protein; cows of superior milking ability (producing 10 kg milk/day will need 11 to 14% of their diet as protein, whereas those of average milking (5 kg milk/day) will need only 9 to 11% protein. Two-year-old heifers will need 10 to 12% protein in their diet.

Beef cows utilize nonprotein nitrogen (urea) as a source of up to one-third of their dietary protein without any deleterious effect (Ryder *et al.*, 1972).

It appears it is as critical not to overfeed protein as it is to feed adequate protein. Ferguson and Chalupa (1989) presented a review paper containing 73 citations, in which it was demonstrated that excessive protein was deleterious to

reproduction in cows. In contrast, Bull *et al.* (1974) concluded "the incidence of weak calf syndrome is related to a deficiency of protein intake by cows during the last trimester of gestation."

C. Minerals

The need for and utilization of minerals by beef cattle are discussed in Chapter 3; the requirements for calcium and phosphorus are presented in Table 11.4. It is not too difficult to meet such requirements under most feeding conditions—especially if a relatively simple free choice mineral mixture is provided. Such mineral mixture might consist of two parts dicalcium phosphate (calcium and phosphorus) mixed with one part ruminant trace mineralized salt (salt, copper, cobalt, iron, magnesium, and selenium). Naturally there are certain situations in which additional amounts of one or more minerals need to be supplied in greater quantities. Examples of this are for certain situations in which soils are especially deficient in one or more of the minerals. In addition, at times of "grass tetany"—or a relative magnesium deficiency—extra magnesium must be consumed by the cow. In fact, as much as 28 g (1 ounce) of magnesium oxide per day is needed to prevent grass tetany in at least some of the cow herd. Although grass tetany has been called a "springtime malady," it has been known to occur at other times of the year. At the time this text was going to press, it had been reported that agronomists and animal scientists at the University of Missouri had been able to produce a "higher magnesium fescue grass," which could be helpful in preventing grass tetany.

D. Vitamins

Supplemental vitamin A should be provided for overwintering cows without access to green forage. However, this is accomplished with a "one shot" injection of 5 million units of vitamin A, injected either subcutaneously (under the skin) or intramuscularly in October or November. This will suffice until the cows are turned to pasture, where they will convert the carotene they consume in their grass to vitamin A.

No other supplemental vitamins have been identified as necessary for the beef cow herd.

III. A YEAR-ROUND FEEDING PROGRAM FOR THE COW HERD

The best adapted feeding program for a cow-calf herd depends on (1) time of year for calving and (2) feeds available. The two most common calving periods are fall and spring, with both systems built around availability of as long a

pasture program as possible. Then, when pasture is no longer available, harvested feeds are introduced. Although no one cow-calf feeding program is suitable for all sections of the country, a typical feeding program is presented from which variations can be made to fit other situations:

A. Spring Calving (February 15 to April 15)

Under this calving date situation, let's assume the calves are born prior to the time that pasture herbage is available. The nutritional advantage to this program is that during the winter when harvested forage must be supplied, the cows are not lactating, and thus feed quantity and quality are lesser. Such calves should be approaching 6 weeks of age by May 1 and, therefore, will start to benefit from this program from the boost in gain they will experience from the tender young grass. Another plus for this program is that lush grass will meet the total needs—except for minerals—of lactating beef cows. The simple free choice mineral mixture listed above (two parts dicalcium phosphate mixed with one part ruminant trace mineralized salt) will be adequate. Once again, in areas and situations where grass tetany may be a problem, special attention needs to be given to providing about 28 g (1 ounce) of magnesium oxide per cow per day during grass tetany season. In such a program, a free choice mineral consisting of equal parts dicalcium phosphate, ruminant trace mineralized salt, magnesium oxide, and ground shelled corn may be offered.

This phase will extend from May 1 to November 1; by that time the calves are weaned and the cows are no longer producing milk. Thus, starting around November 1, the cow feeding program then can revert to a maintenance program until about February 15, when the next crop of calves will start to be born. Table 11.6 lists a number of roughage programs which, when fed with a free choice mineral program, will be adequate for the nonlactating (but pregnant) program.

During lactation and before young lush pasture is available (February 15 to May 15), the cows can be continued on the roughage program outlined for the dry period. However, at this time added energy will be needed and such may be provided by adding 2 to 3 kg of grain per cow/day (Fig. 11.2). This may be difficult to control within the herd because each of the cows would relish four to five times that amount. Therefore, distribution of such a small amount becomes a management problem—but the additional energy is critical since this is one of the very highest energy demands of the cow. If her energy requirements are not met, milk production will decline and calf performance will suffer. In addition, supplemental protein is needed during her lactation. This can be met by supplying a 0.5 kg of a 32% protein source, along with the suggested added grain. Often supplemental protein can be supplied by providing a lick tank containing a 32 to 40% protein liquid molasses–protein product. Cows normally will not overeat liquid supplements provided in this manner.

TABLE 11.6

Roughage Feeding Programs for Nonlactating Pregnant Cows When Pasture Is Not Available

Feedstuff	Dry matter (%)	Intake (as fed) (kg/day)	Protein supplement (32–40% protein) (kg/day)
A. Silages			
Corn silage	40	18.5	
Oat silage	35	26	—
Wheat silage	35	23	—
Haylage	50	15	—
Sorghum silage	35	18	0.5
Grass silage	30	27	0.5
Stalklage	45	27	0.75
Legume haylage	50	18	—
B. Hay			
1. Grass			
Orchard	90	7.5	0.5
Timothy	90	7.5	0.5
Brome	90	7.5	0.5
Fescue	190	7.5	0.5
Bluegrass	90	7.5	0.5
2. Legume-grass, mixed			
Alfalfa	90	7.5	—
Red clover	90	7.5	—
C. Straws and others			
Oat or wheat	90	9	0.75
Corn cobs	90	9	0.75
D. Grazing			
Cornstalks	75–90	*ad lib*	0.75
Dead grass and aftermath	90	*ad lib*	0.75

When the cows and their calves are turned to spring pasture (May 1) about all the supplement they will need is a mineral mixture, probably containing magnesium oxide. Later, if the pasture quantity and quality taper off, attention may be directed toward providing either supplemental energy (grain) or protein.

B. Fall Calving (October 1 to December 15)

In a fall calving system, the cow will not be lactating for all of the pasture season and thus fair to good quality pasture will more than meet all her nutrient needs except possibly minerals. If the pasture is of good quality, most of the cows in the herd will gain weight.

As calving and lactation begin, additional energy and protein will be needed if

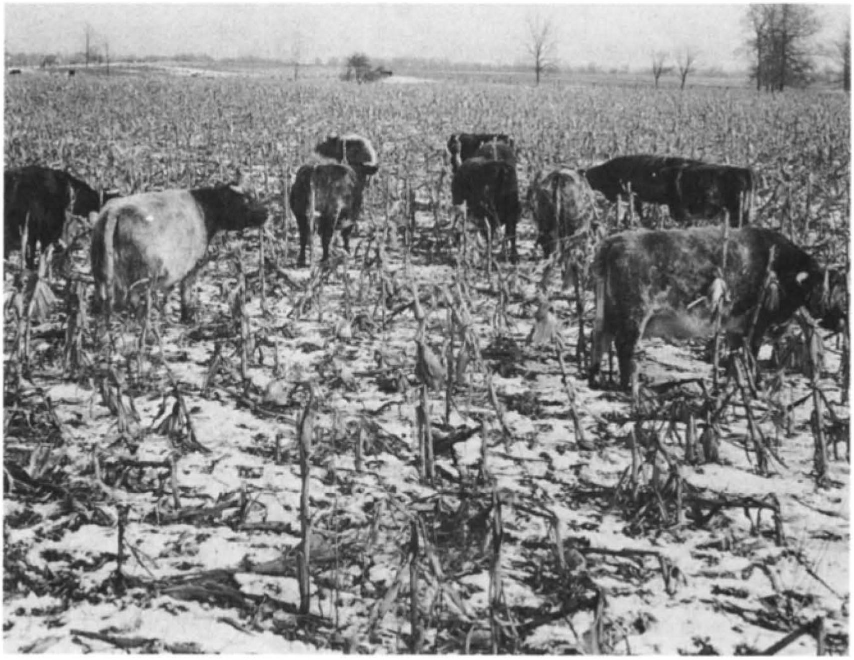

Fig. 11.2 Cornstalks, properly supplemented, make excellent winter cow pasture. (Photo by J. C. Allen and Son.)

optimal lactation is to be achieved. Under this program, pasture is pretty well depleted and so a nonpasture lactation will come into play.

1. Meeting the Protein Requirements

Good pasture and mixed (legume and nonlegume) hays are excellent sources of protein. Normally, on good pasture, or when high-quality legume hay is fed, probably no supplemental protein is required for the lactating cow. In contrast, lactating cows not on good pasture and not being fed high-quality hay will need supplemental protein. The following are some suggested methods for supplying 150 to 250 g of supplemental protein per cow, daily.

a. A minimum of 3 kg clover or alfalfa hay.
b. Soybean meal, cottonseed meal, or linseed meal, 0.5 kg.
c. A 32% protein supplement fed at a level of 0.7 kg/day.
d. A 32% protein liquid supplement offered in a lick tank.
e. Protein blocks fed *ad lib.*

2. Vitamins

Probably the only vitamin requiring attention in the feeding of mature beef cattle is vitamin A. A dry cow requires 25,000 to 30,000 IU of vitamin A daily (Table 11.4); a lactating cow requires 40,000 to 45,000 IU per day. Any one of the following feeding programs will provide adequate vitamin A for the brood cow:

a. Providing at least one-third of the roughage which is green, of high quality, and has been in storage less than 12 months will provide adequate carotene from which the cow is able to synthesize her vitamin A needs.

b. Adding the vitamin via a protein supplement containing vitamin A.

c. An intramuscular injection of 5 million IU of vitamin A, during the wintering season.

3. Minerals

The following mineral elements should be given consideration for beef cows: calcium, phosphorus, salt, iodine, magnesium, zinc, cobalt, and selenium. Any one of the following mineral feeding programs should meet the supplemental needs of the cow.

a. If a commercial protein supplement is fed at the level recommended by the manufacturer, it should supply almost all of the supplemental minerals needed. As a rule of thumb, the complex protein supplement should supply at least one-half the total mineral requirement.

b. Provide a free-choice mineral mixture even if a complex protein supplement containing minerals is fed. This gives cattle the opportunity to consume additional minerals, if they desire. For this, one may purchase a commercial cattle mineral mixture, or a homemade mineral mixture consisting of two parts dicalcium phosphate to one part cattle trace mineralized salt. It is difficult to improve on this mineral mix unless there is a grass tetany problem—then special attention needs to be given to providing magnesium oxide (28 g/day, or 1 oz).

c. Grass tetany periods require that magnesium be provided. Magnesium oxide is a good source of magnesium, but no source of magnesium is very palatable for cattle. A good free choice mineral for grass tetany-suspect situations consists of equal parts of dicalcium phosphate, cattle trace mineralized salt, magnesium oxide, and ground shelled corn.

IV. FEEDING SYSTEMS THAT MEET THE COW'S WINTERING NEEDS

Various combinations of feedstuffs will supply the nutrients for a nonlactating pregnant cow from the end of pasture season (November 1) until calving (Febru-

Fig. 11.3 Large bales provided in racks hold roughage wastage to a minimum. (Photo by J. C. Allen and Son.)

ary 15) and a lactating cow from calving time until pasture is available (May 1) (Fig. 11.3). The following tabulation presents 12 versions of feeding programs which should be adequate for the nonpasture season, for a 550-kg cow; larger or smaller cows would require more or less than designated.

1. Dead grass aftermath, grazed	Nov.1 to May 1
1.8 kg grain per day	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Feb. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
2. Grass hay (7 kg/day)	Nov. 1 to May 1
1.8 kg grain per day	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Feb. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
3. Corn stalks, grazed	Nov. 1 to May 1
Hay (all the cow will eat)	Calving to May 1
3 kg grain/day	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Feb. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
4. Cornstalks grazed	Nov. 1 to May 1
Corn silage (20 kg/day)	Calving to May 1

Protein suppl. (provide 0.2 kg protein)	Jan. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
5. Grass hay (7 kg/day)	Nov. 1 to calving
Corn silage (26 kg/day)	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Jan. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
6. Corn silage (17 kg/day)	Nov. 1 to calving
Corn silage (26 kg/day)	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Jan. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
7. Grass hay (5 kg/day)	Nov. 1 to May 1
Alfalfa hay (2.5 kg/day)	Nov. 1 to May 1
2.5 kg cereal grain/day	Calving to May 1
Minerals, free choice	Nov. 1 to May 1
8. Mixed clover and grass hay (7 kg/day)	Nov. 1 to May 1
Corn silage (9 kg/day)	Calving to May 1
Minerals, free choice	Nov. 1 to May 1
9. Mixed clover and grass hay (7 kg/day)	Nov. 1 to May 1
2.5 kg cereal grain/day	Calving to May 1
Minerals, free choice	Nov. 1 to May 1
10. Haylage (15 kg/day)	Nov. 1 to May 1
2.5 kg cereal grain/day	Calving to May 1
Minerals, free choice	Nov. 1 to May 1
11. Stalklage (all the cow will eat)	Nov. 1 to May 1
Corn silage (9 kg/day)	Calving to May 1
Protein suppl. (provide 0.2 kg protein)	Nov. 1 to May 1
Minerals, free choice	Nov. 1 to May 1
12. Stalklage (all the cow will eat)	Nov. 1 to May 1
2.5 kg cereal grain mix/day	Calving to May 1
Prot. suppl. (provide 0.2 kg protein)	Nov. 1 to May 1
Minerals, free choice	Nov. 1 to May 1

V. CROSSBREEDING AND COW PRODUCTIVITY

Crossbreeding has been recognized as a method of reaping the benefits of so-called hybrid vigor in many species of livestock. Several experiment stations and farm records have demonstrated that crossbred calves grow 5 to 10% more rapidly than their noncrossbred herdmates. Purdue University (Martin *et al.*, 1975) published research data on the effectiveness of crossbreeding a dual-purpose breed (Milking Shorthorn) and a traditional beef breed (Aberdeen Angus). Matings were designed to produce contemporary animals of four breed combinations, (1) 72 Angus (A), (2) 50 Milking Shorthorn (MS), (3) 64 Angus sire times Milking Shorthorn dam (A × MS), and (4) 57 Milking Shorthorn sire times Angus dam (MS × A). The four groups of cows were all bred to Hereford bulls for their first calves and to Charolais bulls for their second calves. The hybrid vigor was determined as the difference between the two crossbred groups

TABLE 11.7

Two-Year Summary of Crossbred Cow Performance[a]

	Breed comparisons			
	Angus (A)	Milking shorthorn (MS)	A × MS	MS × A
First calf				
Weaning wt (kg)	179	191	194	195
Percentage weaned	67	60	81	75
Kg calf/cow exposed	120	114	157	147
Cow wt (kg)	320	319	350	337
Kg calf/kg cow (kg)	17.0	16.3	20.4	19.9
Second calf				
Weaning wt (kg)	194	205	214	210
Percentage weaned	65	55	73	70
Kg calf/cow exposed	126	114	155	148
Cow wt (kg)	340	324	365	344
Kg calf/kg cow (kg)	16.9	17.5	19.4	19.5

[a]Martin *et al.* (1975).

and the two purebred groups. Since no significant hybrid vigor effects on carcass traits were observed, the results shown in Table 11.7 will not make reference to them.

From the last two lines in Table 11.7, it may be observed that crossbred cows produced an average of 33 kg additional calf weight per cow exposed to the bull, which represents an increase of 27% over the average of the purebred cows. This means four crossbred cows produced as much weaning weight as five purebred cows. However, since the crossbred cows were heavier (see last line of Table 11.7), they produced only 20% more weaned calf per unit bodyweight than purebred cows.

The total effect of crossbreeding efficiency seems to be an accumulation of a number of small effects. The crossbred cow seems to breed more promptly; she seems to mother the calf better than the purebred cow. In this particular experiment, the milking ability of the Milking Shorthorn should be taken into consideration and possibly should be weighed heavily in considering crossbreeding programs.

VI. SOME CONSIDERATIONS OF DIET EFFECT ON ESTRUS AND REBREEDING

It is desirable that beef females are bred to calve as near 2 years of age as possible, and that they produce a calf every 12 months. This requires that

nonpregnant females cycle promptly and that they are bred on schedule. Adequate nutrition and management must be given attention in order for these goals to be achieved. In the case of breeding for heifers to calve as 2-year-olds, they should be bred to bulls which are known to sire smaller calves. Turman *et al.* (1964) reported on such a study and noted that heifers calving at 2 years of age needed considerably more assistance at calving time than did those calving as 3-year-olds (Table 11.8). As indicated in a previous section of this chapter, it is critical that during the first winter of a heifer's life she should gain at least 0.5 kg per day if she is to reach puberty by 15 months of age.

From research data that have been presented, it is obvious that breed, weight, daily gain, heterosis, and age affect the appearance of puberty—and first estrus (Tables 11.9 and 11.10). Therefore, in order to obtain estrus as early as possible, replacement heifers should gain about 0.5 kg per day following weaning; mature cows need to be in a gaining condition during at least the last trimester of gestation. Although breed differences may affect the appearance of estrus in heifers, this condition is one that should be taken into account in preparing heifers for their first breeding. In addition to the research of Wiltbank *et al.* (1969, 1965), the research data from many other researchers have emphasized the critical aspect of proper energy levels for breeding cattle—both first-calf heifers and mature cows. Houghton *et al.* (1990) demonstrated the essential nature of feeding cows adequate energy during the last phase of pregnancy, as well as during lactation.

Turman *et al.* (1964) showed the effect of level of winter feeding of heifers on the onset of puberty and thus the first appearance of estrus (Table 11.11). The

TABLE 11.8

Age at Calving and Lifetime Performance[a]

	Age at first calving	
	2 years	3 years
Number of cows	60	60
Number remaining at 12 years	41	42
Years in production	10	9
Calves weaned per cow	9.1	7.9
Percentage calf crop weaned[b]	86.7	85.2
Adjusted calf weaning wt (kg)	216	221
Heifers assisted at calving	28	1
Cow mature wt (kg)	522	535
Lifetime weaned calf wt (kg)	1966	1746

[a]Turman *et al.* (1964).

[b]Based on number of cows bred to calve each year.

TABLE 11.9

Age and Gain Effect on Beef Heifer Puberty[a]

	Breed of cow					
	Angus (A)	Hereford (H)	Shorthorn (S)	A × H	A × S	H × S
			Fed to gain 0.23 kg/day[b]			
Puberty						
Age (months)	13.1	15.5	13.7	13.2	12.1	12.4
Wt (kg)	235	270	227	250	231	237
% showing estrus						
13 months	33	4	25	41	71	64
15 months	77	41	91	91	94	94
			Fed to gain 0.45 kg/day[c]			
Puberty						
Age (months)	11.2	13.6	10.9	11.8	10.2	9.7
Wt (kg)	260	302	247	285	252	246
% showing estrus						
13 months	76	38	73	74	87	97
15 months	92	77	92	77	100	100

[a]Wiltbank *et al.* (1965).
[b]Wintered on range plus 0.45 kg protein supplement/day.
[c]Wintered on 4 kg alfalfa hay plus 2.3 kg concentrate/day.

Oklahoma data illustrated the importance of moderate to high levels of wintering weanling heifers if a high percentage of them is expected to reach puberty by 15 months of age; breeding yearling heifers after 15 months of age will extend the next year's calving period beyond the desirable 60-day limit. Thus such heifers will be expected to be late in calving for many years to come.

TABLE 11.10

Weight at Which Hereford Heifers Reach Sexual Maturity[a]

Weight (kg)	Percentage showing estrus
180	1
204	4
227	17
250	48
272	80
295	94

[a]Wiltbank (1968).

TABLE 11.11

Effect of Winter Feeding Level on Age at Puberty[a]

Age (months)	Winter feeding level		
	Low	Moderate	High
	Percentage reaching puberty		
9	3	3	0
10	17	13	10
11	30	33	47
12	47	57	70
13	60	64	90
14	63	73	93
15	70	90	100

[a]Turman *et al.* (1964).

The data available do not suggest that creep feeding of suckling heifers has any advantage in causing the early appearance of puberty. In fact, there are data from the Indiana Station which indicate that creep feeding of suckling heifers may shorten their productive life by as much as one calf per cow. Supplemental feeding during the first and second winters of replacement heifers is more sensible than creep feeding. Furthermore, excessively rapid gain postweaning—such as heifers selected from the feedlot for breeding which are gaining well over a kilogram per day—is not a wise choice since one of the first sites for the deposition of fat in a finishing heifer is around the reproductive tract.

Too much emphasis cannot possibly be placed upon getting heifers bred to calve at 2 months of age. The data from Table 11.8 demonstrate that heifers bred to calve at 2 years of age, in contrast to those bred to calve at 3 years of age, can be expected to wean one calf more and produce 12% more weaned calf weight (1966 vs 1746 kg) in her lifetime. Furthermore, breeding to calve at 2 years of age did not affect lifetime in the herd.

Growthy heifers can be expected to gain 0.7 kg per day on good pasture, alone, during the pasture season, and during the second winter, as they approach calving, they should be fed moderately well—but not luxuriously; from the end of pasture season to time of parturition, a daily gain of 0.5 to 0.7 kg per day is much more desirable than either less or more.

Why are many cow herd managers reluctant to calve 2-year-old heifers? The data presented in Table 11.8, showing that nearly half of the 2-year-old heifers in the Oklahoma research needed assistance at calving time, probably provide the answer. However, another factor is the generally accepted opinion that 2-year-old first-calf heifers are considerably more difficult than older cows to get bred back promptly. Limited data indicate that the later onset of estrus following the first

calf of 2-year-old heifers results in inadequate energy during the last 3 to 4 months of her first pregnancy. It is recommended, therefore, that one should be fairly certain pregnant yearling heifers receive 3.5 to 4.5 kg of total digestible nutrients (TDN) or 12 to 14 Mcal digestible energy per day during the final stages of their first pregnancy. Since the nutrient requirements for the first calf heifer are so much more critical than those for mature cows, it is an excellent management practice to feed yearling bred heifers separately from mature cows (Fig. 11.1).

Data collected by Wiltbank (Table 11.12) indicate that it takes longer for younger cows (even 3-year-olds) to ovulate—and thus show signs of estrus—for the first time after calving. Furthermore, Wiltbank's data (Table 11.13) demonstrate the critical nature of proper feeding in ensuring prompt appearance of estrus in young heifers.

Energy is without doubt the most important single factor limiting a high level of reproduction in the beef breeding herd. However, other nutrients are critical for reproduction. Protein level during gestation will have an effect on how promptly primigravid heifers will return to estrus following calving. Sasser *et al.* (1988) fed two groups of heifers isocaloric diets (100% energy, NRC), containing either 0.96 kg (adequate) or 0.32 kg (deficient) crude protein/day from 150 days prepartum to 50 days postpartum; they were then group-fed until 110 days postpartum, representing the rebreeding season. The TDN was increased 33% at time of parturition to meet lactation energy requirements. All heifers were bred by artificial insemination when estrus was exhibited, between 45 and 110 days

TABLE 11.12

Effect of Age on Number of Days after Calving That Cows Show Estrus[a]

	Age of cow (years)			
Days after calving	5	4	3 (on crested wheatgrass)	3 (on native pasture)
	Percentage showing estrus			
40	56	26	14	6
50	70	47	32	16
60	82	63	43	28
70	88	72	64	41
80	92	88	77	57
90	95	100	79	70
100	100	100	86	45
110	100	100	86	92

[a]Wiltbank *et al.* (1964).

TABLE 11.13

Reproductive Performance of 2-Year-Old Cows on Different Levels of Energy[a]

Level of TDN					
Before calving	After calving	Number of cows	Cows pregnant after 60-day exposure to bull (%)	Cows not cycling 40 days postpartum (%)	Conception by first service (%)
Moderate (3.6 kg)	High (10.4 kg)	42	81	7	62
Moderate (3.6 kg)	Moderate (5.9 kg)	37	70	5	65
Moderate (3.6 kg)	Low (3.2 kg)	42	64	19	53
Low (1.8 kg)	High (10.4 kg)	41	90	5	73
Low (1.8 kg)	Moderate (5.9 kg)	41	73	17	53

[a]Wiltbank *et al.* (1965).

when the heifers were together and being fed *ad lib.* Eighty-nine percent of heifers fed adequate protein showed estrus whereas only 63% of the protein-deficient cows showed estrus ($p < 0.05$); first service conception for the two respective groups was 71 vs 25% ($p < 0.05$); overall pregnancy rate was 74 vs 32% ($p < 0.05$). These data indicate that reduced protein intake increased the postpartum interval (1) to first estrus, (2) to first service, and (3) to conception.

VII. MEETING SUPPLEMENTAL PROTEIN NEEDS WITH FREE CHOICE LIQUID SUPPLEMENTS

A. Wintering Pregnant Cows

Liquid supplements generally are designed to contain a combination of supplemental crude protein (usually mostly from urea and/or ammonia), minerals, vitamin A, and possibly other nutrients deemed beneficial by the manufacturer; these nutrients are dissolved and suspended in either cane molasses or some modification thereof. Often the source of phosphorus is phosphoric acid. Because of the type of formulation, liquid cattle supplements usually are not especially palatable to cattle, based upon their consumption of it. Thus even though there may appear to be overconsumption of liquid supplements offered *ad libitum*—as from a lick wheel or even an open tank—this tendency generally does not persist unless the other constituents are extremely deficient in either

quantity or quality. Thus, one of the attractive aspects of liquid cattle supplements is that they can be fed *ad libitum* (in general, such supplements are the only ones which can be fed *ad libitum,* with the possible exception of blocks, which are essentially solidified versions of liquid supplements).

The University of Illinois conducted brood cow wintering research at their Dixon Springs Agricultural Center (Saenger *et al.*, 1978), to learn more about consumption patterns and potential benefits for brood cows utilizing liquid supplements offered from a lick tank. Four lots of 32 crossbred cows each were fed grass hay in large round bales on winter pasture from late fall to late April. Each lot consisted of several breed crosses such as Angus × Hereford, Jersey × Hereford, Red Holstein × Hereford, and Simmental × Hereford. The calving season started in early March. Two of the four lots were given access to lick tanks starting in late January; the other two lots did not have access to supplemental protein. The liquid supplement in the tanks contained 32% protein, all from nonprotein nitrogen, 1.5% phosphorus, and 66,000 IU of vitamin A per kilogram. All lots had access to a mineral mixture.

Baled hay consumption was estimated throughout the time the cows received the liquid supplement. The hay was assayed for crude protein and dry matter digestibility. The cows were weighed and assigned a condition score of 1 to 9 in January, and again in April. Cows in the lots having access to the liquid supplement were observed for 2 days approximately every 2 weeks to determine the pattern of liquid consumption within the herd. Consumption was calculated one or more times per week by measuring the depth of liquid in the lick tanks to determine liquid disappearance.

Consumption patterns of the cows varied greatly. Some of the cows visited the tank as often as seven times in an 8-h observation period; others made no visits. The time spent at the tank by individual cows ranged from 0 to 25 min per 8-h observation; average time per visit was 2.58 min.

From the start of the study, average daily consumption decreased from 2 to 0.02 kg for one lot, and from 1.7 to 0 for the other (Table 11.14). Bale hay consumption also varied among lots. The two lots not receiving liquid supplement consumed 46 and 57 large round bales; those receiving liquid supplement consumed 58 and 61 bales. The hay offered to the cows ranged from 5.25 to 8.58% crude protein content, and from 32.5 to 47.2% in digestible dry matter. During the last 2 weeks of the trial, some higher quality hay was fed, ranging from 14.9 to 15.4% crude protein and from 44.8 to 52.7% digestible dry matter. On liquid supplements, offered *ad libitum,* cows tend to self-limit consumption, as illustrated by the dramatic decrease in liquid supplement shown in Table 11.14, during the April period.

Scores for weight loss and change in condition are shown in Table 11.15. Lots 1 and 2 had access to the liquid supplement, whereas lots 3 and 4 did not. The benefit of the supplemental nutrients supplied by the *ad lib* liquid supplement is

TABLE 11.14

Average Daily Consumption of Liquid Cow Supplement Fed Ad Libitum[a,b]

Date		Consumption/cow (kg) Lot 1	Lot 2
Jan.	30	2.1	1.7
Feb.	3	1.6	1.3
	10	1.8	1.4
	11	1.0	—
	13	1.7	2.3
	17	1.5	1.3
	20	1.8	1.4
	21	2.0	1.4
	24	1.7	0.9
	27	0.4	0.5
Mar.	3	1.2	1.0
	6	1.2	1.1
	10	0.8	0.7
	13	1.8	0.6
	20	0.7	0.3
	27	0.3	0.3
Apr.	4	0.1	—
	7	0.08	0.05
	17	0.04	0.03
	21	0.02	—

[a]Saenger *et al.* (1978).

[b]Consumption figures are the average daily consumption of liquid supplement from previous measuring date (kg/cow/day).

TABLE 11.15

Weight Loss in Wintering Beef Cows through Calving[a]

	Free choice liquid supplement			No liquid supplement		
	Lot 1	Lot 2	Average	Lot 1	Lot 2	Average
Number of cows	30	31	61	31	31	62
Weight loss through calving (kg)	−45	−49	−47	−85	−61	−74
Cow condition score[b]	−1.5	−1.3	−1.4	−2.6	−2.2	−2.4

[a]Saenger *et al.* (1978).

[b]Condition scores were 1 to 9 with 9 being fattest.

TABLE 11.16

Liquid Supplement from Lick Tank versus Hand-Fed Dry Supplement for Wintering Pregnant Heifers[a]

	Dry supplement, hand fed, daily	Liquid supplement, *ad lib*, from lick tank
Number of heifers	82	82
Initial weight (kg)	335	339
Supplement consumed/day (kg)	0.9	1.0
Final weight (kg)	364	376
Daily gain (84 days) (kg)	0.35	0.44

[a]Waggoner *et al.* (1977).

obvious, as those which did not have supplementation lost 28 kg and about 1 condition score more than supplemented cows.

Tables 11.14 and 11.15 demonstrate the value of supplemental protein–minerals–vitamin A for pregnant beef cows on a wintering ration of medium- to low-quality hay. Waggoner *et al.* (1977) conducted research to compare pregnant heifer performance on native hay and minerals, either supplemented with a 15% protein liquid supplement, fed *ad libitum,* or hand-fed 0.9 kg of a 15% protein dry range cube. Performance during the 84-day period (December 13 to March 4) is presented in Table 11.16. Heifers having access to the liquid supplement consumed 1 kg of liquid feed per day, and gained 0.44 kg/day; those hand-fed 0.9 kg of the 15% protein dry range pellet gained 0.35 kg/day. The use of the lick tank to provide fortification for low-quality roughage appears to be a sensible labor-saving method.

VIII. UREA FEEDING EFFECT ON CATTLE REPRODUCTION

Urea is a source of nonprotein nitrogen from which cows with functioning rumens can manufacture true protein through a symbiotic relationship existing with the microscopic life which inhabit such rumen. Urea consists of the elements carbon (20%), hydrogen (6.7%), oxygen (26.7%), and nitrogen (46.7%). Since "crude protein" contains an average of 16% nitrogen, multiplying the nitrogen content of a product by 6.25 will give its "crude protein" equivalent. Therefore, urea contains the equivalent of 291% crude protein (46.7% nitrogen × 6.25), meaning that if sufficient units of carbon, hydrogen, and oxygen are present, the microscopic life inhabiting the rumen can utilize urea nitrogen to synthesize utilizable protein for the host cow.

Although urea has been recognized as a potential source of crude protein for

cattle, many people have been unwilling to accept it as a source of economical nitrogen from which cattle can synthesize high-quality protein under optimal nutritional conditions. In fact, allegations of detrimental effects on breeding, rebreeding, cycling, etc., have been raised regarding urea as a source of crude protein. However, scientific evidence which would confirm such accusations does not exist; in fact, scientific data were produced by Ryder *et al.* (1972) which demonstrate that urea was an excellent source of protein for cows being supervised by the Dairy Herd Improvement Association (DHIA) in the State of Michigan. From 1400 DHIA herds in the State of Michigan, over 900 completed questionnaires were returned, representing 85,281 individual lactations and 3157-herd-year observations. The Michigan researchers concluded, "Neither urea fed nor number of years urea was used affected their reproductive efficiency" (Table 11.17). Number of cows per herd averaged 48.6 and milk production per cow was 5776 kg per 305-day period. Average adjusted calving interval for all herds was 315.5 days. Urea was fed in 1709 of the 3157 herd years with an average intake per cow (in those herds where urea was fed) of 81 g per day. Of the total urea, 39.9 g was derived from corn silage, 0.6 g from high-moisture corn, 7.5 g from dry grain, and 32.6 g from commercial supplements. The maximum urea fed to any single herd was 370 g per head, per day (454 g = 1 lb).

Urea feeding had no significant effect on calving intervals or on milk production, although there was a trend for greater milk production from urea-fed cows at higher levels of urea feeding. However, it is possible that higher levels were fed in the better-managed herds—no claim would be made that urea feeding would result in increased milk production.

The author has had the opportunity of observing several beef cow herds in which an unthrifty condition—even some deaths—had been diagnosed as "urea

TABLE 11.17

Relationship of Urea Intake to Calving Interval, Percentage of Cows Sold as Sterile, and Milk Yield[a]

		Urea intake (g/day)					
	Average:	None	79.8	36.1	90.5	146.7	219.5
	Range:	None	1–370	1–60	61–120	121–180	>181
Herd year observations		1442	1715	760	653	219	83
Calving interval (days)		314	316	313	318	316	314
Cows sold as sterile (%)		2.1	2.4	2.4	2.4	2.6	1.7
Milk/cow/year (kg × 1000)		5.9	5.9	5.7	5.9	6.0	6.0

[a]600 DHIA herds from Michigan over a 5-year period. Data adapted from Ryder *et al.* (1972).

toxicity" for cattle in which a portion of the supplemental protein was derived from urea. Upon questioning, it was found that not one such cow had been necropsied by the toxicology laboratory of the state in which the claim was made. The real problem, when all the details of the feeding program were known, was found to be a marked deficiency of energy for the cows. A brood cow needs 85 to 90% of her feed intake and digested nutrients for energy. The reader is requested to refer back to Table 11.5, where the data from Houghton *et al.* (1990) demonstrate that cows whose diet was deficient in energy—but adequate in protein, minerals, and vitamins—had much poorer reproductive performance than comparable cows whose diets had energy levels in compliance with recommended NRC levels. Therefore, a diet grossly deficient in energy, even though supplemented adequately with the other nutrients, can do very little for the cow; she can be expected to lose weight, become unthrifty, and literally starve to death. Brood cows will labor to survive, but if there is insufficient energy (usually in the form of forage), they will "go downhill" quite rapidly.

Cattlemen's fear for the use of NPN as a source of crude protein in cattle diets is generally based on problems arising from the misuse of NPN, improper diagnosis, or stories that have no basis whatsoever.

Consumption of high levels of urea (100 g by a 230-kg calf) in a short period of time by an animal which is not adapted to urea can be fatal. One such experience might be when cattle are in an enclosure where considerable urea has been spilled on the ground where a urea spreader was filled during a fertilizer application. Cattle are curious, and curiosity may be the culprit. If such management is discovered, it is recommended that each of the surviving cattle is drenched with 3 to 5 liters of vinegar (this may have to be repeated a couple of hours later).

Actually, any urea toxicity is a manifestation of ammonia toxicity. Urea breaks down in the rumen—like much of the true protein consumed—to ammonia. When this occurs at a normal rate, the rumen bacteria are capable of synthesizing the ammonia into rumen protein. When the production of rumen ammonia is too rapid, it is absorbed into the bloodstream and carried to the liver. In great excesses, the system is overwhelmed with an ammonia burden and the animal may succumb.

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12

Forages and Environmental Effect on Brood Cows

Tilden Wayne Perry

I. QUALITY OF PASTURE EFFECT ON COW AND CALF PERFORMANCE

The first edition (1980) of this text summarized research (Lechtenberg *et al.*, 1975) to determine the effect of forage species—namely, orchardgrass, tall fescue, or mixtures of tall fescue and legumes (averaged 30% Ladino and red clovers mixture)—on the performance of brood cows and their calves. In the 3-year study, grazing was begun in late April and the calves were weaned off pasture on October 6. Three-year average performance of the suckling calves (205-day adjusted weaning weight) on the three respective pastures were as follows: orchardgrass, 195 kg (429 lb); tall fescue, 160 kg(351 lb); tall fescue–legume mixture, 194 kg (426 lb). Similarly, average nursing cow daily gain over the pasture grazing period was affected by pasture type as follows: orchardgrass, 263 g (0.58 lb); tall fescue, 9 g (0.02 lb); tall fescue–legume mixture, 263 g (0.58 lb). Also, brood cow conception rate reflected pasture exposure rate as follows: orchardgrass, 90%; tall fescue, 72%; tall fescue–legume mixture, 92%.

Since the above data were published, a fungus (*Acremonium coenophialum*) which is common in tall fescue has been identified. Because of the widespread occurrence of this fungus—commonly called endophyte fungus—it is worthy to note how its presence adversely affects the performance of cattle. Tall fescue is very common as a cattle pasture in many parts of the country. A group of 14 researchers have summarized 12 independent studies conducted over a 13-year period at nine locations in seven states (Thompson *et al.*, 1993), to provide combined estimates of the effect of fungus-infested tall fescue on beef cattle performance (Table 12.1). The "mixed model procedure" was utilized to analyze the pooled data sets to provide combined estimates of cattle response from grazing fescue pastures free of (E−) or infected (E+) at different levels with the endophytic fungus. Treatment comparisons included (1) low infestation (5 to 10% E+), (2) moderate infestation (20 to 35% E+), and (3) high infestation (50

TABLE 12.1

Average Daily Gains of Steers Grazing Tall fescue Pastures at Different Levels of Endophyte Fungus Infestation, with and without Clover, during the Spring and Summer Pasture Season[a]

Level of endophyte fungus infestation of tall fescue	Daily gain					
	Spring		Summer		Both phases	
	g	lb	g	lb	g	lb
Low[b]	841	1.85	542	1.19	681	1.50
Medium	757	1.67	525	1.16	672	1.48
High	633	1.39	374	0.82	489	1.07
Low, plus clover	972	2.14	603	1.32	805	1.77
Medium, plus clover	822	1.81	578	1.27	703	1.55
High, plus clover	629	1.39	512	1.13	556	1.22

[a]Thompson *et al.* (1993).
[b]Fescue infestation terms: low = 5% infestation; medium = 20 to 35%; high = 50 to 97%.

to 97% E+), tall fescue, and in tall fescue–clover mixture pastures at the same E+ levels. The clover level in the latter pastures ranged from approximately 10 to 25% in spring and summer pastures. Although the presence of clover in endophyte-infested tall fescue tended to ameliorate the depressing effect of infested tall fescue, the authors made "no speculation as to why the presence of clover had such effect."

Peters *et al.* (1992) utilized the paired-feeding technique with beef cows to compare lactation response from grazing endophyte fungus-infested Kentucky 31 tall fescue, endophyte-free Mozark tall fescue, or Hallmark orchard grass pastures. Milk production of the KY-31 (infested) cows was 25% lower ($p < 0.01$) (6.08 vs 8.0 kg/day), and calves from the cows on KY-31 gained more slowly (0.72 vs 0.88 kg/day).

II. FEEDING CROP RESIDUES

Typical crop residue chemical analyses are shown in Table 12.2. When beef cow daily nutrient requirements are matched with what they can obtain from typical crop residues (Table 12.3), it is obvious that most crop residues alone cannot meet total beef cow nutrient requirements. If crop residues are to be used successfully, in beef cow diets, the nutrient deficiencies should be corrected (Table 12.4). Otherwise, such cows may lose weight and condition and may experience difficulty in calving and recovery. Nutrient-deficient cows may fail to return to estrus promptly after calving, and wean smaller calves.

TABLE 12.2

Typical Nutrient Composition of Crop Residues

Product	Dry matter (%)	Analysis of dry matter (%)			
		Protein	TDN	Calcium	Phosphorus
Cornstalks	20–80	5	45	0.16	0.13
Cornstalk silage	35	5	50	0.16	0.13
Corn cobs	90	2.5	47	0.12	0.04
Soybean straw	87	4.3	40	0.90	0.10
Wheat straw	90	2.3	45	0.17	0.03
Grass aftermath	80	5	45	0.40	0.20

A. Soybean Straw

Soybean straw is lower in feeding value than cornstalks and most other residues. This is because soybean straw consists mainly of stems and few, if any, soybean leaves. However, many of the pods may still be attached to the stems after the harvesting process, and thus would improve the feeding value of the

TABLE 12.3

Beef Cow Nutrient Requirements and Nutrients Supplied by Normal Daily Intakes of Crop Residue

	Dry matter		As-fed intake		Protein		TDN		Ca	P
	lb	kg	lb	kg	lb	kg	lb	kg	(g)	(g)
	Beef cow requirements, daily[a]									
Nonlactating cow, mature, last one-third pregnancy	22	10	—	—	1.7	0.8	12	5.5	26	21
Lactating cow, mature	23	10.5	—	—	2.1	1	13	6.0	28	23
	Nutrients supplied by crop residue									
Cornstalk silage	20	9.1	57	26	1.0	0.5	10	4.5	13	13
Cornstalk stacks	14	6.4	16	7	0.7	0.3	6	2.8	4	4
Corn cobs (ground)	18	8.2	20	9	0.5	0.2	9	3.8	9	4
Soybean straw	13	5.9	15	7	0.6	0.3	5	2.4	54	4
Wheat straw	15	6.8	16	7	0.4	0.2	7	3.1	13	—
Dead grass aftermath	15	6.8	19	9	0.8	0.3	7	3.1	27	13

[a]Requirements based on National Research Council (1984).

TABLE 12.4

Supplemental Feed Recommended with Corn Residue for Mature Beef Brood Cows

	Supplementation suggested, per head/day			
	Protein (32% protein suppl.)		Energy feed	
Product and situation	lb	kg	lb	kg
Grazing dry residue				
Dry cow, first 7 months	none		none	
Dry cows, last 2 months	1	0.45	3 (hay, corn)	1.4
Lactating cow, fall calving				
First months	1	0.45	none	
Last 2–3 months	2	1	4 (hay, corn)	1.8
Ensiled corn residue				
Dry cow (50 lb or 23 kg)	0.5	0.23	none	
Lactating cow (60 lb or 27 kg)	2	1	3 (corn)	1.4

soybean straw. Cows grazing soybean fields following combining will require approximately 680 g (1.5 lb) of a 32% protein supplement per head, daily. Once the leaves and pods have been consumed, supplemental hay or grain should be added. Studies at Iowa State University indicate that cows grazed on soybean fields with access to soybean straw stacks and protein supplement could maintain body weight for at least 100 days during winter. However, it is generally recommended that the utilization of soybean straw should be restricted to nonlactating cows; furthermore, some supplemental protein (680 g of a 32% supplement/head/day) should be fed. Additionally, either some free choice hay or 1 kg of a grain mix should be added.

B. Small Grain Straw

Wheat straw is likely the most available of the small grain straws in most regions of the country. Wheat straw can be utilized to supply a part of the energy of dry pregnant beef cows. It is best to use it in combination with high-quality roughage such as grass–legume hay. Feeding 3.5 to 4 kg (8 to 10 lb) of grass–legume hay/day, plus a full feed of wheat straw, will provide sufficient protein and energy for mature dry cows. If less hay is fed, cows should receive 0.5 to 0.7 kg (1 to 1.5 lb) of a 32% protein supplement/head/day. Figures 12.1 and 12.2 illustrate typical large hay packages that are stored out of doors for winter feed for brood cows.

Fig. 12.1 Large hay packages, properly shaped, can be stored out-of-doors for up to 1 year without great nutrient loss.

C. Dead Grass Aftermath

The use of pasture aftermath as a feed for beef cows is satisfactory as long as such material is available and when the weather permits grazing. Aftermath grazing often is practiced in combination with the use of hay—perhaps large

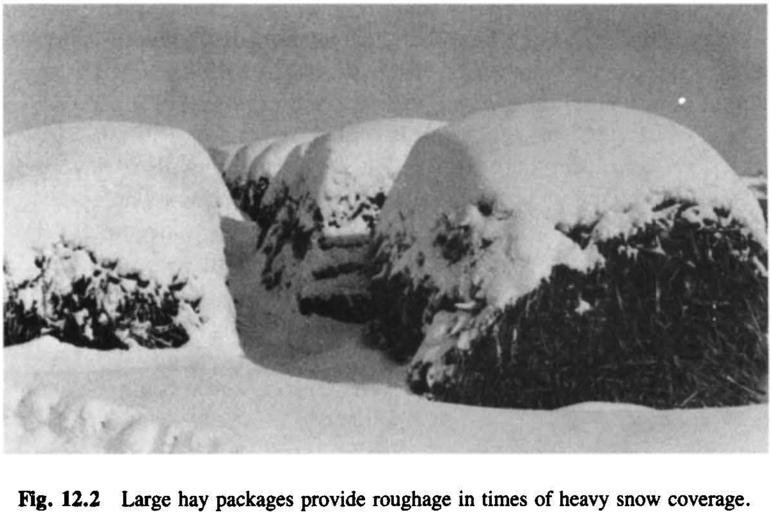

Fig. 12.2 Large hay packages provide roughage in times of heavy snow coverage.

packages offered in pasture manger devices. Naturally, the need for supplemental protein depends upon the protein content of the aftermath plus that of the hay that is provided. For example, first-cutting hay harvested before midbloom generally will not require supplemental protein with pasture aftermath. However, hay of poorer quality likely will be deficient in protein, along with the aftermath. In this case, cows should be fed 0.5 kg (1 lb) of a 32% protein supplement/head/day.

D. Corn Cobs

Corn cobs may be available in certain areas. In order to obtain satisfactory intake by cows, the cobs should be ground prior to feeding. Since cobs may be quite dry, ground corn cobs work well in complete mixed rations. A mixture of 90% ground corn cobs plus 10% of a 32% protein supplement, fed at the rate of 7 to 8 kg (16 to 18 lb) per day, will provide the protein and energy needs of nonlactating brood cows. Adding 5% cane molasses to the mixture will increase the intake by cows and decrease the dustiness of the mixture. For lactating cows, a mixture of 65% ground corn cobs, 20% ground shelled corn, and 15% of a 32% protein supplement can be fed *ad libitum* to provide all the protein and energy needs during lactation.

III. GRAIN SORGHUM STOVER FOR BEEF COWS

Combine-type grain sorghum is a perennial grass which acts as an annual where killing frost prevails. Since it is a perennial until frost, the stover continues to accumulate dry matter during the period between grain harvest and killing frost. Data indicate that after combine harvest, 50 to 60% of the total dry matter of grain sorghum remains in the field, as compared with estimates of only 45 to 50% of the corn plant remaining. Grain sorghum stover remains standing after grain harvest, making it conducive to harvest, later in the season, by either animals or a forage harvester.

The harvest of grain sorghum stover for dry stacking with a hay packaging machine does not seem feasible under Corn Belt conditions unless the stubble is mowed and allowed to dry before stacking. The moisture content of dry stacks should be less than 40% in order to prevent spoiling and/or run the risk of internal combustion. Because of this, grain sorghum stover utilization in the more humid Corn Belt usually should be limited to either ensiling or grazing in the field.

In an Iowa study, dry pregnant cows (heifers and mature cows) were grazed on grain sorghum stover for a 98-day period at a stocking rate of 0.6 ha (1.5 acres) per cow. The combined heads and tailings of the grain sorghum were collected and stored at the end of the field as a reserve feed supply. Snow cover

occurred from December 20 through late January, plus intermittent snow cover during February and March. The cows received a mineral–vitamin A supplement the first 42 days, and a 32% liquid protein supplement was available free choice (lick wheel) during the last 56 days.

For the first 42 days, the mature cows gained 20 kg (44 lb) and the bred heifers gained 2.7 kg (6 lb); over the last 56 days, both mature cows and the heifers essentially held their weight, neither gaining nor losing. The average liquid supplement consumption for the last 56 days was 1 kg.

An obvious advantage of the sorghum stover was the availability of standing forage when heavy snow cover occurred during the last half of the test, whereas cows grazing cornstalk pasture required supplemental hay. The sorghum stover leaves were selectively grazed during the first half of the wintering period which resulted in much poorer forage during the last period. This was evidenced by the lack of weight gain, even with the additional consumption of 1 kg liquid supplement during the latter half.

The study showed that sorghum stover provided approximately 26 grazing cow days per hectare (65/acre). Mature cows were maintained adequately by the grazing program, but weight gains for bred heifers were inadequate, indicating the need for supplemental energy for normal growth and development under such a program.

When grazing grain sorghum, producers must be aware of possible prussic acid poisoning. Grain sorghum stover may be utilized safely by cattle after a killing frost if the cattle are kept from the stover for 3 days following the killing frost. The frost must also have killed completely any new shoots which have appeared after grain harvest for cattle to safely graze the stover.

IV. CORN RESIDUE UTILIZATION BY BEEF CATTLE

Corn stalks represent the plant material remaining after the corn grain has been removed. Actually, such residual makes up about 50% of the dry matter of the corn plant. Moisture content of it will vary greatly (from 20 to 75%) which affects the method of harvest and storage. Realistically, within a week or two after the grain harvest, much of the residual leaves and husks may have been removed by the wind. There are several methods which have been proposed and investigated for utilizing corn residue as a cattle feedstuff. Corn residue is a cellulose and lignin-containing feed with very little protein and a TDN value of about 40%. It is low in calcium and phosphorus, but fairly high in potassium (1.6%). The product is useful as a low-quality roughage (energy feed), primarily for pregnant brood cows, or for maintaining stocker cattle at a low level of gain.

Admittedly, corn residue has quite good feeding potential when managed under the proper conditions. Therefore, it is worthwhile to consider alternative methods for handling and feeding it.

A. Field Grazing

1. Normally the grazing period will be between October 1 and February 1.

2. On an average, 1 ha (2.2 acres) of stalks is required to carry one cow for approximately 100 days.

3. For most efficient utilization of cornstalk material, cows should be restricted to one-fourth ha (half an acre) per cow for each 4- to 5-week period. A hot wire might be employed to restrict the cows within a designated grazing area.

4. Less than one-fourth of the stalks available are actually consumed by the cow.

5. If more than the normal amount of corn grain is left in the field behind the picker–sheller combine, caution should be taken to prevent the cows from consuming too much of the grain corn or else digestive disturbances might occur. If this is the case, such cows should be restricted to much smaller areas for the first week or two.

6. There are obvious disadvantages to field grazing: (a) fencing must be provided; (b) fall plowing is not possible—at least this will delay it; and (c) on muddy days the cows may tramp much of the feed potential into the ground, which also has an undesirable effect on the subsequent physical quality of the soil.

Fig. 12.3 The equipment illustrated here gathers husks, cobs, and bypassed grain into stacks. (Photo courtesy of BEEF Magazine.)

B. Combine Trash—Accumulated and Stacked

1. In this process the husk, cob, some leaves, and any bypassed grain is collected in a trailer behind the combine instead of being scattered on the ground. Once the trailer is filled, the material is dumped at random in the field or moved to one side or end of the field (Fig. 12.3).

2. When the stacks are placed at one end of the field in a concentrated area, a hot wire may be used to restrict access to a limited number of stacks or to only a portion of one stack.

3. Yield of this product may run as high as 1 metric ton per acre.

4. The advantages include (a) less fencing is required, (b) frees corn fields for plowing, and (c) stacks usually are higher than the snowbanks when snowfall occurs.

5. Disadvantages include (a) cost of equipment plus labor involved, (b) more management is required to control (cows love to get on top of the stacks and lie down), and (c) cows do not eat the whole cobs and so in the spring these must be scattered.

C. Whole Stalks Collected in Large Packages

1. Large machines will make packages from 454 kg (1000 lb) and upward (Fig. 12.4).

2. Yield of product may run 4.4 metric tons/ha (two tons/acre) and more.

3. Feeding management is similar to that for the combine-accumulated trash listed above.

4. Advantages and disadvantages of this type of harvest are similar to those for combine-collected trash, listed above.

D. Ensiling Corn Stalk Residue

1. The material is harvested utilizing methods (B) or (C) above and hauled to a tub grinder where it is chopped; from the tub grinder, the material is mixed with water to promote fermentation and prevent spoilage, and then ensiled. This method does not enhance the feeding value of the product, but helps retain status quo, plus the grinding enhances more nearly total consumption of the product. When fortified with vitamins, protein, and minerals, ensiled corn residue is an excellent energy feed for dry pregnant cows; the addition of 2 to 3 kg (4 to 6 lb) per day makes the above mixture a lactation diet for mature cows.

2. The great disadvantage of this method is the overall cost of getting the mission accomplished. Furthermore, the timing of the harvesting of corn residue is both unpredictable and competitive with fall plowing. Unfortunately, few people pursue this route of harvesting and storing the corn residue.

Fig. 12.4 Cornstalks stored in large round bales. (Photo courtesy of BEEF Magazine.)

V. DRYLOT VERSUS CONVENTIONAL COW HERD MANAGEMENT SYSTEMS

Traditionally, many beef cow herds must depend on the marginal land in the farming operation for feed source, including pasture and hay, with an assist from cornstalk residue for a part of the post-corn picking season. As land values have grown in value, fencing costs have also risen. One might consider a beef cow herd in confinement 12 months out of the year. A 4-year study was conducted at Purdue University to study three beef cow herd management systems which included a complete confinement program (Perry *et al.*, 1974).

In this program, mature commercial Hereford cows bred for spring calving each year were maintained in their three respective 25-cow herds for the 4-year test. The cows in each herd were bred naturally to performance-tested Hereford bulls. Bulls were rotated among herds; calves were born outside in February and March. All calves were weighed, ear tagged, and tattooed at 1 day of age. Creep feed was not available. The cows were hot-branded for permanent identification.

The research was adapted to three rather obvious naturally occurring phases from calving to weaning. All cows and calves were weighed individually at the beginning and end of any particular phase. Phase I was from the time the calves

were born until the "permanent pasture" herd was placed on bluegrass pasture; Phase II was the interval between start of the permanent pasture grazing until summer annual pasture was available for the "temporary-pasture" herd to graze; Phase III started when the temporary-pasture herd went to pasture and ended when this pasture was depleted or killed by fall frost. Calves were weaned and weighed when this phase was completed.

A. Permanent Pasture Herd (Bluegrass Pasture, Cornstalks, Hay)

From May through October, this herd grazed bluegrass (permanent) pasture on land which did not permit alternative cropping. For the 4-year period, bluegrass was grazed an average of 158 days during the summer period, and carried an average of 1.5 cow–calf units/ha (0.6/acre). In other words, it required 0.7 ha (1.73 acres) for a cow and her calf for the 5-month grazing season. It should be pointed out that varying grazing capabilities might be realized if other species of plants were incorporated into the pasture program, but this also might greatly increase the investment cost in the pasture.

Cornstalks were grazed an average of 89 days for this herd. Finally, 675 kg (1486 lb) of medium-quality mixed hay was required to round out each cow's needs for the year (Table 12.5).

B. Temporary Pasture Herd

This herd was started on sorghum–sudan grass hybrid pasture around July 1 each year. The temporary pasture seeding was on 9.4 metric tons/ha (150 bush-

TABLE 12.5

Herd Treatments

Herd	Diet	Calendar period
Permanent pasture	Bluegrass pasture	May–Oct.
	Cornstalk pasture	Nov.–Jan.
	Mixed hay	Feb.–April
Temporary pasture	Bluegrass pasture	May–June
	Summer annual	July–Sept.
	Bluegrass aftermath	Oct.–Nov.
	Corn stover silage	Dec.–April
Total confinement	Corn silage, 60 lb/day (27 kg/day)	May–Sept.
	Corn silage, 25 lb/day (11 kg/day)	Oct.–Nov.
	Corn silage, 30 lb/day (14 kg/day)	Dec.–April

els/acre) corn land which had been plowed and disked with potash plowed down; anhydrous ammonia was applied prior to planting, and starter fertilizer was placed in the row. Seeding was made in mid-May with a corn planter in 96-cm (38-inch) rows and then doubled back so the rows were 48 cm (19 inch) apart. The resulting growth was divided into three subpastures for rotational grazing. Each of the subpastures was clipped after the cattle were moved from it to the next rotational pasture; adequate grazing pressure resulted in only some central stubble remaining. This pasture was grazed an average of 97 days per season by 3 cow–calf units/ha (1.25/acre), or 0.33 ha/cow and calf (0.81 acre).

When the summer annual was gone, the herd had access to aftermath bluegrass pasture until corn stover silage was ready. The winter feeding program consisted of corn stover silage plus a balancing 32% protein supplement. When spring perennial pasture was ready, this herd was switched to it until July 1, when summer annual pasture was ready (Table 12.5).

C. Total Confinement Herd

This herd was not kept under shelter, but rather was quartered on a small amount of land (1.2 ha, or 3 acres) that was devoid of herbage at a population of 24 cows/ha (10/acre). During the heaviest lactation (May through September), corn silage was fed at a rate of 27 kg/cow (60 lb), along with 0.9 kg (2 lb) of a 32% protein balancing supplement. Since the calves did not have access to a creep, it is obvious the calves tended to compete with their mothers for the feed provided. Immediately after calf weaning, the level of corn silage fed was dropped to 11.3 kg/day (25 lb), and the supplement fed was reduced to 454 g/day (1 lb); as the cows approached parturition, corn silage feeding was increased to 13.6 kg/day (30 lb). Naturally, these latter two levels of corn silage feeding did not satisfy the hunger of the brood cows, but over a 4-year period no ill effects appeared.

Average corn silage yield was 37 metric tons/ha (17 tons/acre) (65% moisture), and each cow–calf unit consumed 6.7 to 7.1 metric tons (7.5 to 8.0 tons); nearly 5 cow-calf units can be fed for 1 year from 1 ha corn silage yield (2+ cow–calf units from 1 acre). A comparison of feed budgets for the three systems is presented in Table 12.6. Examination of the feed budget from this table would give the obvious feeling that cost favors the "permanent pasture" reared calves. Nevertheless, the data include the possibility of either of the other two systems if the price of either feeder calves or sale of purebred calves warrants it. The research demonstrates the adequacy of each of the three systems for producing healthy weanling calves. Calf performance—at least weaning weights—was comparable for all three methods (Table 12.7). However, it should be noted that calves in the "total confinement" group did not gain as rapidly as those in the other herds during May and June. This could be explained by the fact that they were too small to compete with their dams at the feed bunks when corn silage and

TABLE 12.6

Feed Budget for Three Systems of Managing Brood Cow Herds (4-Year Summary)[a]

Cow herd program, material fed, amount fed	
I. Permanent pasture herd	
Permanent blue grass pasture	180 days
Cornstalk pasture	80 days
Mixed hay	100 days, 1486 lb (675 kg)
Supplemental mineral mixture	
II. Temporary pasture herd	
Permanent bluegrass pasture	78 days
Summer annual pasture	90 days, 0.81 acre (0.33 ha)
Bluegrass aftermath pasture	60 days
Corn stover silage	137 days, 1.7 tons (1.5 metric tons)
32% protein supplement	136 lb (62 kg)
Supplemental mineral mixture	
III. Total confinement herd	
Corn silage	7.7 tons (6.9 metric tons)
32% protein supplement	475 lb (216 kg)
Supplemental mineral mixture	

[a]Perry *et al.* (1974).

TABLE 12.7

Birth to Weaning Performance and Annual Performance of Cows Due to Treatments (4-Year Average)[a]

	Herd description					
	Permanent pasture		Temporary pasture		Total confinement	
Total number of calves	93	93	89	89	91	91
Birth weight of calves	75 lb	34 kg	76 lb	35 kg	91 lb	41 kg
Daily gain of calves						
Birth to May 1	1.68 lb	762 g	1.58 lb	717 g	1.63 lb	740 g
May and June	1.89 lb	858 g	1.79 lb	813 g	1.40 lb	636 g
July to October	1.51 lb	685 g	1.71 lb	776 g	1.81 lb	823 g
Birth to weaning	1.66 lb	753 g	1.71 lb	776 g	1.64 lb	745 g
Calf weaning weight	445 lb	202 kg	454 lb	206 kg	449 lb	204 kg
Cow net weight change	−50 lb	−23 kg	13 lb	6 kg	−7 lb	−3 kg

[a]Perry *et al.* (1974).

supplement were fed. By July, though, the calves "muscled" up to the feed bunk and obtained a reasonably fair share of feed. Meanwhile, starting in July, calves in the permanent pasture herd were finding shorter droughty pastures and their rates of gain declined during that period. Most consistent calf gains were made by those in the temporary pasture herd where fairly good pasture was available right up to weaning time. Naturally, some of the poorer calf gains might have been improved had a creep diet been provided.

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13

Milk Production and Calf Performance

Tilden Wayne Perry

There is an abundance of research data which demonstrate that level of milk production by the dam is related closely to performance of the calf. Clutter and Nielsen (1987) utilized three groups of cows, similar except for genetic potential for milk production (205-day milk production for the three groups averaged: high, 1718 kg; medium, 1532 kg; low, 1157 kg), in which 205-day milk production of the high-milk-production group exceeded that of the medium- and low-production groups by 186 and 251 kg, respectively. Pooled within milk correlation between calf gain to 205 days and milk production was 0.60. Calves suckling high-milk-group dams had 16.9 kg greater 205-day weaning weights than those on the low, and maintained 63% of that advantage in a postweaning growth-finishing period prior to slaughter.

Neville *et al.* (1962) reported on 3 years of research on the subject. In this 3-year study, 8-month milk production among 135 cows ranged from 181 to 1909 kg. Milk production was related to weight of the calves at 60 days of age, but remained important throughout. Sixty percent of the 8-month weight variation was due to milk production. Rutledge *et al.* (1971) utilized 193 Hereford cows in 279 lactations to study the effect of several environmental factors on milk production. They concluded that 60% of the variance in 205-day calf weight could be attributed to the direct effect of the dam's milk yield. Furthermore, it appeared that milk quantity had most influence on calf weight, whereas milk quality (percentage protein, solids-not-fat and fat) had small but nonsignificant correlation with calf weight. The Rutledge study identified significant quadratic responses in milk yield due to age of dam and calving date, with peak milk yield occurring at 8.4 years of age for this group of cows.

Oklahoma researchers (Wyatt *et al.*, 1977) used a unique approach to determine milk level effect on calf performance. Hereford and Friesian cows were employed in a system designed to expose calves of two biological types to a low (Hereford) or high (Friesian) level of milk. Two distinct biological calf types were produced by breeding Hereford cows to Angus bulls and Friesian cows to Charolais bulls. Then a reciprocal cross-fostering scheme was utilized in which

half of the calves born to Hereford dams (A × H) were nursed by Friesian cows and, conversely, one-half the calves born to Friesian dams (C × F) were nursed by Hereford cows. Thus, within each biological type, some calves obtained a low level of milk (4.2 to 5.5 kg per day) while others obtained a high level of milk (9.5 to 11 kg per day), based upon periodic calf-suckle estimates. In addition, cow–calf pairs were maintained either on tall grass native range or in completely confined drylot. The performance of A × H and C × F calves consuming low- and high-milk yields is summarized in Table 13.1

Under range conditions, and within the A × H breeding, calves on high milk were 52 kg heavier ($p < 0.05$) at weaning, representing a 20% increase. Drylot calves of the A × H group were 44 kg heavier ($p < 0.05$) on the high level of milk. Within the C × F group, calves on high milk and on range gained 50 kg more (22% more) and those in drylot gained 61 kg more (23% more) than comparable calves on low milk.

Corah and co-workers (1977, 1993) presented data from which it can be concluded that adequate energy in the diet of the pregnant beef cow may be critical possibly only for the last 30 to 45 days of gestation (Table 13.2).In this comparison, two groups of cows were fed low levels of energy (1.9 kg TDN—a 500-kg cow should receive 1.9 kg TDN for the middle third of pregnancy) for the last 100 days of pregnancy; then, starting 30 days prepartum, the "high energy"

TABLE 13.1

Milk Level and Biological Type Effect on Calf Performance[a]

	Breed of calf and level of milk			
	Angus × Hereford		Charolais × Friesian	
	Low milk	High milk	Low milk	High milk
	Range environment			
Number of calves	13	9	9	14
Daily milk consumed (kg)	5.4	10.9	5.0	10.0
Birth weight (kg)	30	34	40	47
Weaning weight, 240 days (kg)	232	279	255	313
Daily gain to weaning (kg)	0.84	1.02	0.90	1.11
	Drylot environment			
Number of calves	9	9	9	9
Daily milk consumed (kg)	5.0	10.0	5.0	10.0
Birth weight (kg)	30	32	45	42
Weaning weight, 240 days (kg)	226	270	245	298
Daily gain to weaning (kg)	0.82	1.00	0.83	1.06

[a]Wyatt et al. (1977).

TABLE 13.2

How Long Prepartum Do Beef Cows Need Added Energy?[a]

	Energy levels	
100 days prepartum, TDN/day (kg):	1.9	1.9
30 days prepartum, TDN/day (kg):	4.8	1.9
Cow weight (kg)		
100 days prepartum	450	450
30 days prepartum	398	396
A few days prepartum	440	386
Weight change last 30 days	42	−10
Cow fat cover (cm)		
100 days prepartum	0.41	0.43
Just prepartum	0.18	0.05
Calf Statistics		
Birth weight (kg)	30.3	26.7
Calves alive at birth (%)	100	90.5
Calves alive at 2 weeks (%)	100	80.9
Calves alive at weaning (%)	100	71.4
Calves suffered scours (%)	33	52.0
Calves died due to scours (%)	0	19.1
Cow milk production/day (kg)	5.5	4.1
Interval for cows to first estrus (days)	41.6	49.5

[a]Corah *et al.* (1977) and Corah (1993).

cows were fed 4.8 kg TDN to parturition (requirement for 500-kg cow is 5.1 kg), whereas the "low-energy" cows continued receiving 1.9 kg TDN to parturition. Note the improved calf performance of the high-energy cows (heavier birthweight, 100% weaned calf crop vs 71%, death loss due to scours, 5.5 vs 4.1 kg milk production, and shorter interval to estrus), compared to that of the low-energy cows.

I. CHOOSING A PROFITABLE COW SIZE

The data in this chapter show the effect of level of milk production by the dam on calf weaning size; the data imply an extra 18 to 22 kg at weaning time favoring a large breed of calf (Charolais × Friesian) on either the high- or low-milk regimen (Table 13.1). Naturally, size of the weaned calf has a great bearing on the monetary return to the cow owner. Although it is not possible to recommend one specific type of feeder calf, there is a demand for almost any healthy feeder calf when offered at the right price. Normally, the larger sire–dam breed-

ing program will produce the larger calf (Table 13.1); likewise, the dam which produces most milk will tend to wean heavier calves. It must be borne in mind that either "big cow" or "heavy milker" will cost considerably more in terms of energy required by the dam. An average size cow (500 kg) requires 4.3 kg TDN/day on a maintenance situation; a 600-kg cow requires 14% more energy (4.9 kg TDN/day). The larger cow also requires 14% more protein. The larger cow requires more energy than the smaller cow (6.2 vs 5.2 kg) to give the same amount of milk (5 kg milk/day). When one compares the energy requirement for a cow producing more milk with that of another cow of the same size, the increased energy needs of the dam producing more milk become obvious. A 500-kg cow producing 5 kg milk/day requires 5.6 kg TDN/day, whereas a 500-kg cow producing 10 kg milk/day requires 6.9 kg TDN/day, according to the 1984 NRC recommendations. One must calculate, then, how much extra TDN one can afford to feed to either the larger cow or the cow producing more milk.

What does the feedlot operator want in terms of size? It has been pretty well established that when cattle are fed to the same compositional endpoint (USDA grade), larger, faster-gaining cattle do not have an advantage in efficiency of feed conversion; larger, faster-gaining cattle have an advantage only if slaughtered on a weight constant basis. Therefore, desirable weight of a feeder calf may be related more to the price of feedstuffs, in that when corn is relatively low in price, money can be made in the long feed and thus operators will pay more for lighter cattle; when feed is high, and when interest rates are high, more will be paid for the yearling 300-kg plus feeder that can be upgraded quickly and moved out quickly. Except under exceptional weather conditions, corn and sorghum

TABLE 13.3

Influence of Body Size on Dam's 365-Day Maintenance Energy Requirement (Exclusive of Milk Production)

	Energy requirement for 365-day maintenance[a]		
Cow weight (kg)	Total digestible nutrients (TDN) (kg)	Net energy maintenance (Mcal)	Percentage required for 454-kg cow
350	1204	2274	82
400	1314	2514	90
450	1460	2745	100
500	1570	2971	107
550	1679	3193	115
600	1788	3405	122
650	1934	3617	132

[a]National Research Council (1984).

TABLE 13.4

Distribution of Calf Mortality by Disease or Condition Class[a,b]

Disease or condition	No. of deaths	% of all deaths
Reproductive tract	375	34
Dystocia	193	17.5
Stillbirth	137	12.4
Abortion (premature birth)	39	3.5
Birth defect	6	0.5
Enteric	146	13.3
Undifferentiated diarrhea	100	9.1
Remainder (coccidiosis, enteritis, etc.)	46	4.2
Respiratory tract	88	8.0
Unidentified infection	69	6.3
Remainder (diphtheria, suffocation, etc.)	19	1.7
Sudden death/clostridial disease	58	5.3
Clostridial enterotoxemia	18	1.6
Drowning	16	1.5
Predator	13	1.2
Others	11	1.0
Miscellaneous	217	19.7
Hypothermia	134	12.2
High mountain disease	33	3.0
Other causes	50	4.5
Not determined	217	19.7
Total deaths	1011	100.0

[a]Data collected from 73 Colorado cow–calf operations over a 2-year period, involving 24,396 calves. Of these births, 1101 calves (4.5%) died prior to weaning. The National Health Monitoring System was utilized in collecting the data.

[b]Hermel (1993).

grains have been "bargain-priced" for a number of years. Naturally, politics such as embargoes and import quotas can change that relationship overnight.

The calf producer likes to produce a heavy weaned calf (high sale price) from as small a cow as possible (low inputs) because the cost of maintenance (exclusive of milk production) is related directly to her size. The influence of size of the dam on energy maintenance requirements is shown in Table 13.3. The relative energy requirement expressed as a percentage of that required by a 450-kg cow is shown and can be visualized also as relative land requirement. Thus, if a 450-kg cow requires 4 ha on a given range, a 650-kg cow requires 32% more land, or 5.3

TABLE 13.5

Combined Weight and Milk Production Effect on 365-Day Energy Requirement of a Beef Cow[a]

Cow weight (kg)	Daily milk (kg)	365-day TDN (kg)	No. of cows[b]	TDN equivalent as hay (kg)
454	4.5	1550	100	3100
454	9.0	1869	83	3738
636	4.5	1979	78	3958
636	9.0	2295	68	4590

[a]Totusek (1975).
[b]Relative number of cows which could be supported by energy requirement by 100 cows weighing 454 kg and producing 4.5 kg milk daily during lactation.

ha, merely for maintenance purposes. Further, if a $90.00 land charge is assessed for a 450-kg cow, the 650-kg cow would incur a land charge of $108.80. The additional energy to support a higher level of milk production has not been estimated. On the other hand, the greater salvage value of the heavier cow partially offsets her additional maintenance cost.

The apparent weaning efficiency of a small cow may be misleading, especially if she calves a small, early-maturing calf which is apt to be discounted in the auction ring. This problem can be offset, somewhat, by the use of a large growthy bull, except that dystocia (calving difficulty) may become a real problem (Table 13.4). Furthermore, to produce small dams, it is estimated that a herd

TABLE 13.6

Necessary Weaning Weight of Calves for Cows Varying in Weight and Milk Production[a]

Cow weight (kg)	Daily milk (kg)	Number of cows	Necessary weaning weight (kg)[b]	Total calf produced (kg)	Necessary weaning weight adjusted for cow salvage (kg)[c]
454	4.5	100	214	19,227	214
454	9.0	83	257	19,218	257
636	4.5	78	274	19,241	259
636	9.0	68	315	19,222	299

[a]Totusek (1975).
[b]Based on a 214-kg calf by 454-kg cow with 4.5 kg daily lactation and 90% calf crop.
[c]Based on the assumption that the productive life of a cow will be 6 years. An additional year is assessed for the development of the replacement female, so 26 kg additional salvage is available each from the larger cows (182 kg divided by 7 years = 26 kg). Since cows have a market value approximately 60% that of calves, 16 kg (26 kg × 60%) less necessary weaning weight is required for larger cows.

of 60 cows would be needed to maintain a 100 cow herd of the small specialized cows. The economics of such a program, including the small "by-product" steers from the herd producing the small females, must be considered.

The data in Table 13.5 set forth the combined body size and milk requirements for energy for beef cows, based on research by Totusek (1975). The TDN figures might be more meaningful if visualized as feed. Good-quality nonlegume hay contains about 50% TDN, so if the TDN requirements are doubled, one could have hay requirements as a benchmark, to compare energy requirements needed to support the four cow situations for 365 days. A 454-kg cow producing 4.5 kg of milk per day would need the equivalent of 3100 kg of good nonlegume hay equivalent to support her energy needs for a year; a 636-kg cow producing 4.5 kg of milk per day during lactation would require 3958 kg of good-quality nonlegume hay for the same period of time. The same comparisons may be made on pasture land or on a combination of hay and pasture land. Totusek (1975) concludes that increased weaning weights (shown in Table 13.6) indicate heavier weaning weights but are not necessarily correlated with larger cow size.

II. CREEP FEEDING BEEF CALVES

A program of management which provides energy feeds other than milk, plus grass or hay, usually is defined as a creep feeding arrangement. Naturally, not all farms and ranches lend themselves to this management technique, which requires additional labor, equipment, and feed. However, creep feeding usually results in increased calf gain during its suckling period (Fig. 13.1). In fact, many plain type calves have been fattened sufficiently on a creep feeding program to sell as heavy fat calves, although such programs are not too common in the United States.

Creep-fed suckling calves will make more rapid gains if their total diet—including their milk—is well balanced, in addition to any pasture or hay to which they will have access. However, since milk is such a good source of protein, calcium, phosphorus, and vitamins, and is lacking primarily in energy, supplemental energy will require primary consideration in designing a good creep diet. Creep feeding may be expected to make a difference in calf performance at almost any time of the year, but the greatest benefit may be expected when pasture or hay is of less than optimal quality and quantity. With lower-quality forage, a decline in milk production by the dam can be anticipated; also, there is less quality forage for the suckling calf. Varying results as to the potential benefits for creep feeding suckling calves can be found in the literature; it probably is dependent considerably upon a combination of milk production by the dam and quality of forage available to dam and calf.

Purdue University (Perry *et al.*, 1974) demonstrated one of the more ideal situations for recommending creep feeding for suckling calves (Table 13.7). Under such conditions, the dams and their calves were restricted to drylot—or

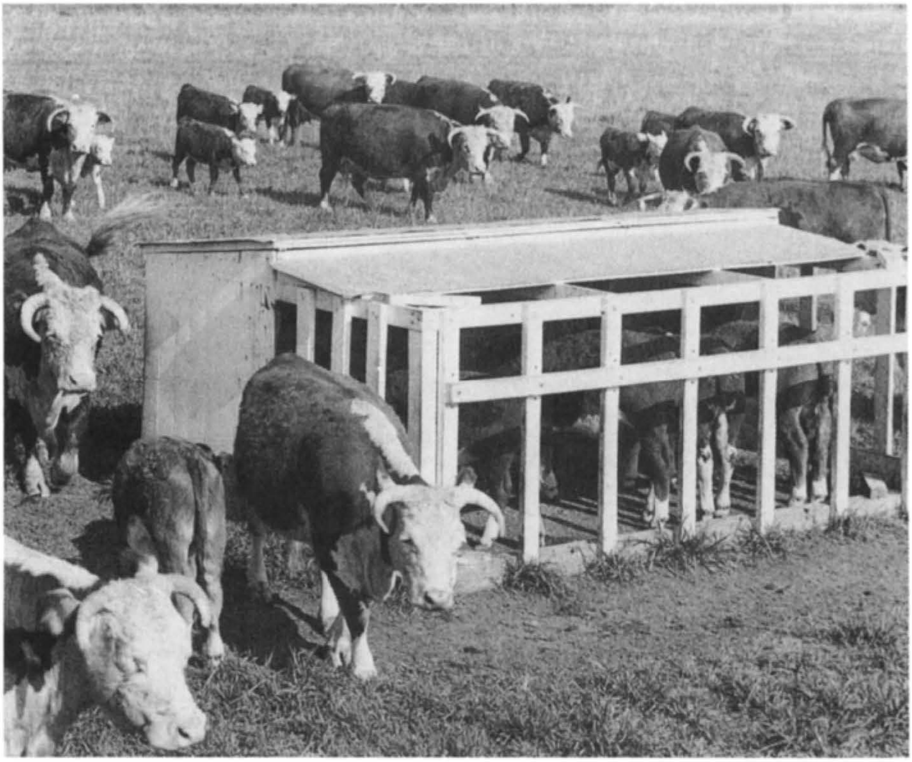

Fig. 13.1 Creep feeding of calves running with their dams on pasture can produce heavier weaned calves. (Photo by J. C. Allen and Son.)

TABLE 13.7

Value of Creep Feeding Calves in Drylot[a]

	Trial No.					
	1 (53 days)		2 (60 days)		3 (71 days)	
	No creep	Creep	No creep	Creep	No creep	Creep
Number of calves	27	27	35	34	35	35
Initial weight (kg)	137	136	142	145	159	161
Final weight (kg)	172	192	184	204	204	241
Gain/calf (kg)	35	56	42	59	45	80
Daily gain (kg)	0.66	1.05	0.70	0.98	0.63	1.13
Daily creep consumed (kg)	—	1.45	—	1.18	—	3.04
Feed/extra kg gain (kg)	—	3.9	—	4.2	—	6.4

[a]Perry *et al.* (1974).

TABLE 13.8

Grain Preference for Creep-Fed Beef Calves[a]

	Year (No. of days)	
	1 (126)	2 (138)
Number of calves	48	50
Initial age (days)	64	49
Initial weight (kg)	69	61
Final weight (kg)	173	173
Daily gain (kg)	0.82	0.81
Average daily feed, first 60 days (kg)		
Rolled corn	0.18	0.30
Rolled barley	0.20	0.20
Rolled oats	0.01	0.05
Average daily feed, total period (kg)		
Rolled corn	0.76	0.98
Rolled barley	0.37	0.45
Rolled oats	0.02	0.02

[a]Anonymous (1961).

extremely sparse pasture conditions. In this study a herd of Hereford cows and their calves was restricted to drylot as part of a long-term study. During the lactation phase, from approximately May 1 through September 30, whole-plant corn silage was fed at a level of 27 kg, along with 0.9 kg of a complex 32% protein cattle supplement, per day. The free-choice creep diet available to the calves consisted of two parts whole shelled corn to one part whole oats, by weight. Table 13.8 presents the preference of calves for some typical feed grains.

III. IMPLANTING SUCKLING CALVES

The value of growth-stimulating implants for suckling calves is worthy of discussion because of the variations in results that have been reported. By careful selection of trial data, one can identify quite positive growth benefits for calves which have been implanted with such products. However, when the data from intensive surveys are compiled, benefits from such practices appear less than dramatic. In the first edition of this text (1980), the author drew from a study (Corah *et al.*, 1977) in which data from 62 implant demonstrations from 31 different counties in Kansas were summarized. A total of 1402 implanted suckling calves weighed an average of 6.86 kg more than 694 nonimplanted controls. In an up-to-date version of this practice, Corah and Blanding (1992) summarized

TABLE 13.9

Effect of Implanting Suckling Calves on Weight Gains (19-Trial Summary)[a]

Study	No. calves	Days on test	Control	Ralgro	Syn-C	Compu-dose	Calf-oid
				Daily gain (kg)			
Texas	54	170			0.06		
IMC (JAS)	195	175	0.98	1.05	1.04		
Virginia	90	196	0.61	0.69	0.66		
Virginia	59	130	0.72	0.75[b]		0.69	
Australia	112	79	0.66	0.70		0.78	
Missouri	64	182	0.46			0.61	
Florida	82	210		0.10			
Louisiana	228	270	0.75	0.78[b]		0.78	
Illinois	336	220	0.63	0.68	0.65	0.68	
Colorado	717	153	0.90	0.95	0.95		
Colorado	116	157	0.89	0.97[b]	0.96[b]		
Colorado	39	168	0.74	0.82		0.82	
Colorado	172	145	0.93	0.94		0.95	
Kentucky	60	167	0.72	0.71	0.77		
Arkansas	60	209	0.67				0.73
Michigan	540	205	0.92	1.00		0.98	1.01
Kansas	179	164	0.93	0.94		0.95	
Oklahoma	239	244	0.66		0.70		
South Dakota	628	163	0.96	0.99	1.00	0.98	
Total	3960						
Average		175.6					

[a]Corah (1993). Studies conducted from 1984 to 1990.
[b]Calves that were reimplanted. Average implant response was 8.45 kg, or 0.05 kg/day.

19 trials (Table 13.9) from various locations in the United States—and one from Australia—for results gathered between 1984 and 1990. A total of 3960 calves were involved in trials, ranging from 79 to 270 days, which utilized four types of implants cleared for this use (Table 13.9). Corah summarized the results by indicating an "average implant response of 8.45 kg" for implanted calves. Based on the "average" trial length of 175.6 days, this gave a daily response of 0.05 kg. The response was fairly consistent, but was rather small, overall. Thus, cow–calf operators must weigh the pros and cons of such practice according to their own situation.

IV. EARLY WEANING OF BEEF CALVES

Early weaning of beef calves is possible and sometimes may be practical. Most cow–calf operators will agree that it is most difficult to improve on a good

nursing cow as a source of nutrients for the young calf. However, when pastures dry up and when harvested roughages are not so available, it might be worthy of consideration to wean calves as early as 4 weeks of age. Louisiana State University (O'Neal *et al.*, 1977) researched such a program and found that it was workable; the 205-day adjusted weaning weights of such calves were not significantly different from those which had nursed their mothers for the same 205 days. In the LSU program, early weaned calves were confined to small indoor pens when pasture was not available and then moved to relatively small pasture plots when spring and summer pasture was available. The early weaned calves at 2 and 4 weeks of age were given access to some grass hay and water in addition to the diets listed (Table 13.10).

The LSU data appear to indicate that it is more advantageous to wean the calves at 4 weeks of age, but in an emergency they can be weaned at 2 weeks. For about the first 60 to 90 days of age the early weaned calves should have access to a diet similar to Diet No. 1 (LSU diet); Diet No. 2 (no milk replacer) might then be substituted until the calves reach 205 days of age. Several cases of calf scours were observed in the early weaned calves, but this did not seem to occur in the calves nursing from their mothers. However, the scours problem was alleviated by rotating the calves among clean pens combined with recommended drug therapy.

It is difficult to assess an economic comparison of this program since feedstuffs are not the only costs involved. A great deal more labor and management are involved in early weaning calf programs.

TABLE 13.10

Early Wean Calf Formulas[a]

Ingredient	Diet No. 1 (first 60–90 days) (%)	Diet No. 2 (to 205 days) (%)
Corn	37.3	42.9
Oats	22.0	21.5
Soybean meal (49%)	22.0	32.2
Calf Manna[b]	15.4	—
Curaphos[c]	1.1	1.1
Salt	1.1	1.1
Vitamin-antibiotic mix	1.1	1.1
Total	100.0	100.0

[a]O'Neal *et al.* (1977).
[b]Albers Milling Co.
[c]Calcium, 35%, and phosphorus, 14%.

TABLE 13.11

Approximate Composition of Colostrum and Normal Holstein Milk

Constituent	First milk (colostrum)	Second and third day (colostrum)	Regular milk
Fat (%)	6.0	3.5	3.5
Nonfat solids (%)	22.3	12.5	8.8
Protein (%)	18.8	7.5	3.25
Immune globulin (%)	13.1	1.0	0.09
Lactose (%)	2.5	4.0	4.6

An interesting aspect of early weaning—or early calf removal from the dam—is its effect on rebreeding the dam. Houghton *et al.* (1987) studied this effect; between two groups of cows, one group of calves was removed from their dams at 30 days of age, whereas the other group of calves remained with their dams until they were 7 months of age. Early calf removal resulted in a shorter postpartum interval (53.1 vs 77.4 days). Conceivably this is a management technique which might be utilized when one wishes to shorten annual calving interval.

In considering early weaning, one should be reminded of the critical nature of colostrum for the newborn calf. Colostrum is the first milk produced by the dam after parturition. It differs greatly from regular milk in composition (Table 13.11), and has functions that have long-reaching effects. One of these differences is the high level of immune globulins (protein) which give the calf a temporary immunity against infections of the respiratory and digestive systems. The immune globulins are true protein and are readily absorbed, intact, into the blood system. This peculiar absorbability persists in the young mammal for only 2 to 3 days, and then is gone for the life of the calf. Therefore, a calf that is slow to nurse should be force-fed some of its mother's first milk in order to receive the immune globulins. Colostrum also is much richer in vitamin A than normal milk (another name for vitamin A is the "anti-infections vitamin," meaning it helps the young calf fight off infections). The newborn calf should receive about 6% of its body weight of colostrum within 8 h of birth—for a 32-kg calf, this means approximately 2 kg of colostrum.

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IV

Finishing Beef Cattle

14

Starting Cattle on Feed

Tilden Wayne Perry

I. THE PROGRAM

A recommended program for handling newly purchased feeder cattle upon their arrival at their new feedlot home is presented. Naturally, it would be expected that most feedlot operators would plan to impose various modifications in this program. However, it is quite a workable program when followed in principle.

1. Isolate the new cattle so that they are not adjacent to cattle which are already "adjusted." This author has experienced an outbreak of "shipping fever" in cattle which have been on site for 6 weeks, undoubtedly via exposure to new cattle which were brought in and penned adjacent. It is therefore a good idea to have receiving pens where the isolation adjustment phase may be managed away from the other cattle.
2. Clean dry quarters should be available where the new cattle may rest following a long, uncomfortable transit period.
3. Cattle should not be crowded. At least 40 square feet (3.72 square meters) per animal under roof is desirable—especially during rainy periods (Figs. 14.1 and 14.2).
4. It is best to have shed-type shelter in the receiving pens to give cattle the option of shelter or open air.
5. Fresh clean water is critical since cattle tend to become dehydrated on long hauls. If drainage is good, it is especially desirable to use overflowing tanks. Automatic individual waterers should be avoided since new cattle usually are unacquainted with the use of such equipment.
6. The timing of hormonal treatments and treatment for grubs, lice, and worms varies. The large commercial operator prefers to give the complete treatment to new cattle immediately upon arrival—right "off the truck." Others prefer to administer the typical veterinary shots at this time, but to delay such things as growth implants, worming, and administration of degrubbers until the cattle have passed through the 3-week shipping fever period. Either management technique

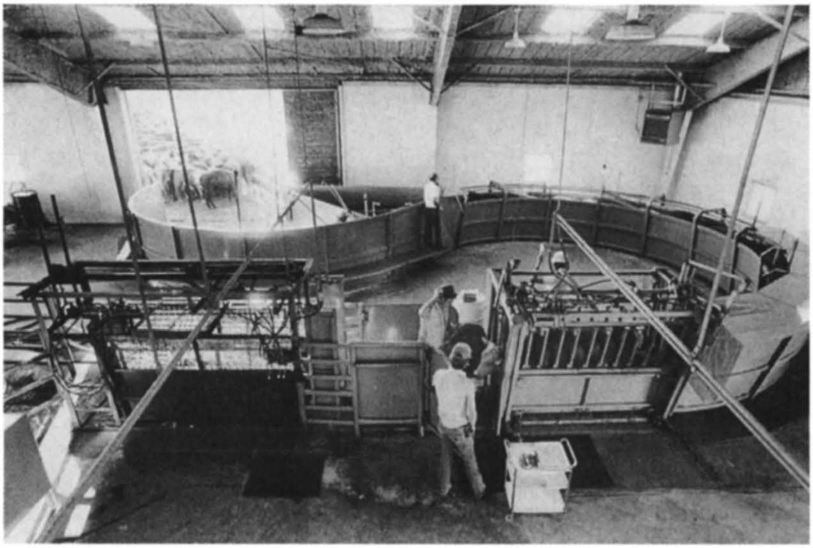

Fig. 14.1 Excellent working facilities enhance handling cattle rapidly and efficiently. (Photo courtesy of BEEF Magazine.)

Fig. 14.2 New feeder calves should have loose hay scattered about the lot for at least the first three to four days. (Photo by J. C. Allen and Son.)

will have about the same net effect, so the timing is left to the discretion of the operator.

7. Shots to be administered as a preventative for the typical feedlot diseases of cattle will vary somewhat from one locale to another. These should be determined based on the problems typical of the area and in consultation with your veterinarian.

8. Treatments for external parasites may be handled by spraying, dipping, pour-ons, or injection. There is no single best method of accomplishing this task. A couple of such methods are illustrated in Figs. 14.3 and 14.4.

9. Warble eradication must be handled with an understanding of the place of origin of the animal, so that one may be able to predict the stage of the life cycle of the warble. If the warble is killed at the wrong time in its movement through the cow's body, a severe protein shock may be experienced by the treated cow. A qualified entomologist—probably through a state university—should be contacted to assist in establishing the proper time for warble eradication in cattle.

10. Parasites of the gastrointestinal tract may be handled at the time of arrival. Very effective subcutaneous injectables are available; also, pour-on systemics are available. People who are not knowledgeable are encouraged to contact the USDA livestock agent for their area for advice on types of parasite controls.

11. The Aureo S-700 program (feeding 350 mg each of aureomycin and sulfamethazine per head daily for up to 21 days, or even as long as 28 days) is an excellent inclusion for the conditioning program. Many researchers, including this author, have demonstrated the beneficial effects of the program. Aureo S-700 should be administered in a natural protein supplement.

12. Even though the cattle should have been injected with vitamin A in the "shots" step, it is a good practice to feed 50,000 IU of vitamin A per head, daily, during the adjustment period. If the cattle have been injected with 2.5 million IU, no more vitamin A is needed following completion of the adjustment period.

The above program presents general guidelines that need to be considered in the starting period. The specific day-to-day regimen of the first 21 to 28 days is given below.

Arrival. Administer the shots, vitamin A injection, worming, if necessary, hormone implant, and the required external parasite treatment. Bunches of medium- to poor-quality hay should be provided in hay feeders. A free choice mineral mix should be available which contains phosphorus, calcium, salt, and trace minerals. In fact, a free choice mineral mix of two parts dicalcium phosphate to one part trace mineralized salt is excellent. The cattle should be immediately placed on their Aureo S-700 medication which can be mixed into a protein supplement. Actually, it is also advantageous to put a mixture of 2 lb (0.91 kg) of corn and 2 lb of natural protein supplement per head daily in the bottom of the

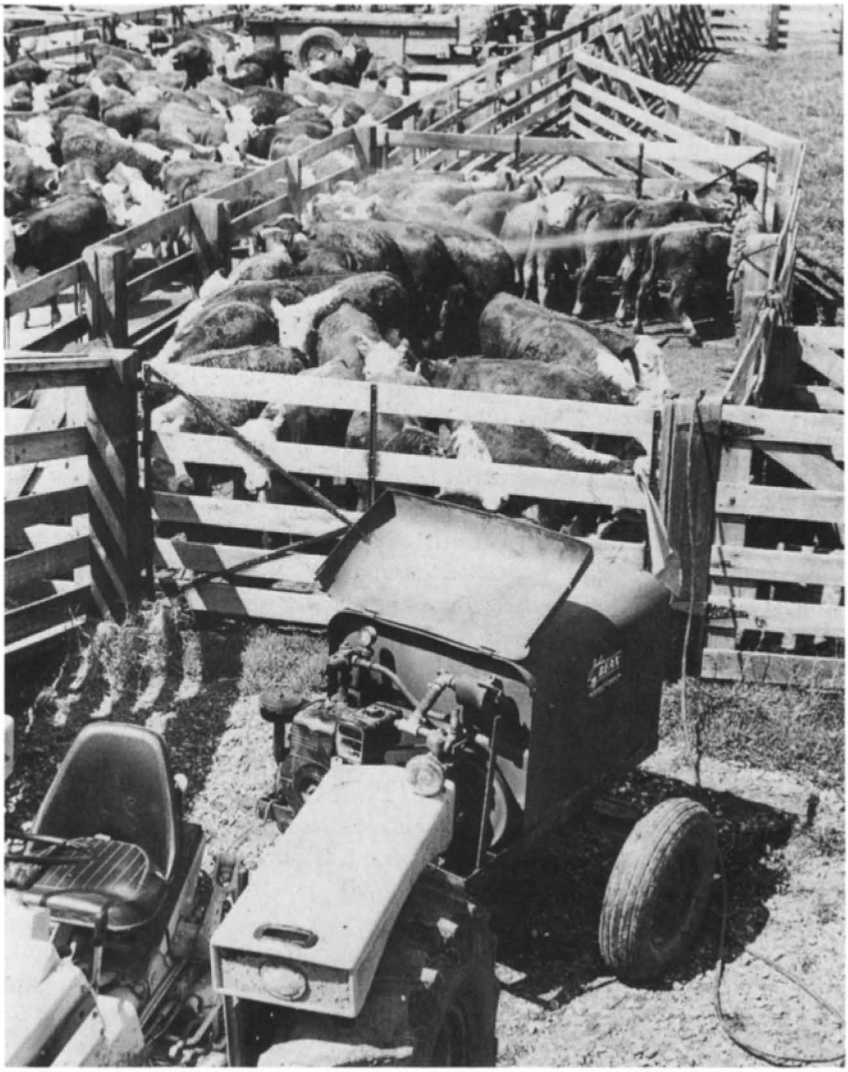

Fig. 14.3 External and internal parasites should be controlled at all times. (Photo by J. C. Allen and Son.)

bunk and then put a thin layer of their hay on top of the grain mix to begin the feeding program.

Day 2. The same general program as for the first day is followed—limited corn and supplement under a little hay, plus other hay offered in a separate bunk, perhaps.

Fig. 14.4 Dipping vat with hold-down rack. The hold-down rack prevents the animals from jumping on top of each other. (Photo courtesy of Temple Grandin, Tempe, Arizona.)

Day 3. Introduce the cattle to corn silage. Mix the 2 lb (0.91 kg) of supplement containing the Aureo S-700 and 2 lb of corn with 4 lb (1.4 kg) corn silage and place on the bottom of the feed bunk, then place a little hay on top of this mixture.

Day 4. Continue to introduce the cattle to more and more corn silage if the feed from the previous day was used satisfactorily. Incorporate 7 or 8 lb (3.2–3.6 kg) into the mixture of corn and medicated protein supplement.

Days 5–7. Hopefully all the trough-fed hay can be dispensed with by this time because the cattle will have become adjusted to the corn silage. Feed whatever corn silage the cattle will utilize as evidenced by "slicked troughs." Along with the corn and supplement, by now the cattle should be eating 20–25 lb (9–11 kg) of corn silage.

Days 7–21. This time should be used for a gradual introduction to a much higher, "hotter" diet. During this period, if the response and health of the cattle are appropriate, they may have been moved from the receiving pens to their permanent pens.

Day 21 onward for the next several weeks. The cattle should now be adapted to the management changes they have experienced. The high moisture corn, or steam-flaked grain, plus the high-urea supplement programs can now be initiated. Ionophore feeding (Rumensin, Bovatec, Catalyst) should be in place now.

II. STARTING NEW CATTLE ON CORN SILAGE

Starting new cattle on feed is a major problem facing cattle feeders. During the stress of weaning, assembling at sales barns, and at least two trucking experiences, calves will lose as much as 10% of their body weight. Probably more than one-half of this is intestinal loss, but the other portion is a combination of tissue loss and dehydration. Cattle thus arrive at the feedyards somewhat depleted nutritionally and need wholesome feed promptly.

Michigan State University (Fox *et al.*, 1977) conducted a series of trials to compare methods of getting new cattle started. This section summarizes that research. The data presented are from trials varying in length from 28 to 46 days (but primarily 28 days), which corresponds to the typical feedlot adjustment period.

A. The Value of Adding Hay to Corn Silage

In the research summarized in Table 14.1, 455-lb (207-kg) calves trucked nearly 2000 miles were fed silage which had been treated with a liquid–urea mixture (Pro-Sil) to create a 12% protein corn silage. This was compared to cattle fed this silage with or without the addition of 1 lb (0.45 kg) soybean meal per 20 lb (9.1 kg). Also, this was compared against the addition of alfalfa-brome hay. In summarizing five such experiments, there was no advantage to offering hay in addition to the corn silage. In four of the five experiments, gains were decreased by the feeding of additional hay.

The apparent explanation for the difference in performance is that those fed hay had similar dry matter consumption to those fed only corn silage, resulting in lower energy intake. Cattle having access to hay tended to eat more readily the

TABLE 14.1

Value of Added Hay in Starting New Feeder Cattle on Corn Silage[a]

	Corn silage		Corn silage plus hay	
	lb	kg	lb	kg
Daily gain	1.93	0.88	1.72	0.78
Difference			−0.21	−0.10
Daily dry matter consumed	9.8	4.45	9.7	4.40
Dry matter/unit of gain	5.2		5.8	

[a]Fox *et al.* (1977). Five experiments, 252 cattle.

first few days, but those fed only silage adjusted quickly and their consumption increased rapidly. However, a little hay may be desirable and necessary for the first few days in order to attract new cattle to the feed bunk promptly.

B. Hay plus Grain versus Corn Silage

Feeder calves, 460 to 490 lb (210–220 kg), were fed either corn silage treated to contain 12% crude protein or else a mixture of hay, corn, and soybean meal, such that the two diets were isocaloric and isonitrogenous. In all cases, those fed the hay plus corn diets had the highest rates of gain, but there was very little difference in dry matter required per unit of gain (Table 14.2). Furthermore, there is some evidence suggesting that cattle started on a hay diet will still require an adaptation period to adjust to a changeover to a silage feeding program.

C. Value of Corn Added to Corn Silage

Table 14.3 gives the results of one experiment in which 50% silage, 50% concentrate diet was compared to an all-silage diet. Cattle fed the higher grain diet gained about 10% more rapidly (1.89 versus 1.72 lb/day, or 0.86 versus 0.78 kg). However, the performance is approximately 12% less than would be expected based on the comparative energy levels of the two diets, suggesting that greater benefit may be obtained from fortification of corn silage with extra energy after the cattle are started on their regular feeding program.

D. Mineral Programs for New Cattle

Minerals represent one of the prime considerations for new cattle. Limestone and salt are relatively inexpensive, but the phosphorus supplements are much

TABLE 14.2

Hay and Corn Compared to Corn Silage for Starting New Feeder Cattle[a]

	Corn silage only		Hay plus corn	
	lb	kg	lb	kg
1. Calves				
Daily gain	1.49	0.67	1.90	0.86
Difference	−0.41	−0.19		
Daily dry matter	9.4	4.27	12.2	5.54
Dry matter/unit gain	6.4		6.4	
2. Yearlings				
Daily gain	3.85	1.75	4.23	1.92
Difference	−0.38	−0.17		
Daily dry matter	16.4	7.45	18.5	8.41
Dry matter/unit gain	3.9		4.8	

[a]Fox *et al.* (1977). Two experiments with calves (66 head), 1 experiment with yearlings (50 head).

more expensive to provide. It seems that feeder cattle often arrive at their new destination with an almost depraved appetite for phosphorus—especially those which have been brought directly from range pastures where it is less easy to provide access to minerals. A complicated mineral mixture is not required to meet the basic mineral needs of cattle. A mineral mixture of two parts dicalcium phosphate to one part of trace-mineralized salt mixed together and offered at all times will meet practically all of the supplemental mineral needs—especially if a well-fortified protein supplement is used.

TABLE 14.3

Value of Added Corn for Starting New Cattle on Corn Silage[a]

	All silage		50% silage:50% corn	
	lb	kg	lb	kg
Daily gain	1.72	0.78	1.89	0.85
Difference	−0.17	−0.07		
Daily dry matter	9.0	4.01	9.2	4.18
Dry matter/unit gain	5.3		5.0	

[a]Fox *et al.* (1977). One experiment, 132 cattle.

III. FEEDING REGIMENS FOR NEW FEEDER CATTLE

A. Hay Program

New feeder cattle tend to take to hay readily since it is so much like the dry range forage to which they were previously accustomed. High-quality legume hay should not be used for new cattle because it may tend to cause some looseness of bowel, which would facilitate additional dehydration. Rather, a predominantly grass hay that is free of mold and weeds would be better suited for such cattle. The bunks should be loaded with such hay when the cattle arrive so that they can get some material in their rumens just as soon as they desire it. In addition, the simple mineral mixture referred to above plus clean water should be available continuously. This diet is exceptionally good as a receiving diet, but by Day 2 or 3 it must be expanded to provide 2 lb (0.90 kg) each of a grain such as shelled corn plus a protein supplement which will supply 50,000 IU of vitamin A and 350 mg each of an antibiotic and sulfamethazine, per day.

The mechanics of feeding hay plus 2 lb each of corn and supplement can be worked out if some hay is offered in a tight-bottom bunk; the corn and supplement can then be placed in the bottom of the bunk, and then the day's aliquot of hay placed on top of the concentrates. Thus, in order for the cattle to get the very palatable concentrates, they will have to burrow through the hay.

B. Corn Silage Program

Whenever corn silage is available, it is a most excellent basis for a conditioning program because of its relatively high energy value and its high palatability. However, the cattle feeder should bear in mind that most new feeder cattle have never seen corn silage, so that problems associated with the introduction of this type of diet should be considered. To start a silage program, it is a good idea to begin with medium-quality grass-legume hay to which cattle can relate readily. Then for the first day or two, utilize a hay program; by the second or third day, introduce the silage program by putting the concentrates and silage on the bottom of the bunk and covering it with a thin layer of hay. Cattle will discover the silage rapidly and decide it is a pretty delightful feed. A good introductory level of corn silage at this introductory phase is from 8 to 10 lb (3.6 to 4 kg) per day. Similar to the hay program listed above, cattle on the silage program should be given 2 lb (0.91 kg) each of shelled corn and a natural protein supplement containing 50,000 IU of vitamin A and 350 mg each of an antibiotic and sulfamethazine. This medical program should be continued for at least the first 21 days after the arrival of the cattle.

C. Hay as a Rumen Regulator

Dry hay—or dry pasture aftermath—is an important feedstuff as the first feeding for new cattle, as indicated in the above two sections. By starting with a hay program for at least the first 2 or 3 days, the cattle then can be transferred over to almost any other program the manager desires. Furthermore, when feedlot problems may appear later in the program, going back to at least some medium-quality hay will have a stabilizing effect on the cattle. It seems that hay exerts a "rumen-regulating" effect. The rumens of most new arrivals are usually in fairly poor condition and are in need of reconditioning before concentrate formulations are begun. Furthermore, if the receiving lot is dry, hay may be used in the open, scattered on the ground, for new cattle. Introducing cattle to concentrates too rapidly may be conducive to initiation of acidosis in new cattle. Added hay initially will speed the sequence of getting the rumen back into good condition.

D. Soybean Meal versus Urea as Sources of Protein in the Receiving Diet

The Ohio Research Center (Anonymous, 1975) demonstrated that use of natural protein supplements, as contrasted to urea supplements, on newly received feeder calves is best for the first month. Feeder calves averaging 400 lb (182 kg), initially, were full-fed limestone-treated (0.5%) corn silage plus 2 lb (0.91 kg) of a fortifying supplement containing trace mineralized salt, Vitamin A, aureomycin, and sulfamethazine (AS-700), plus either soybean meal or urea and corn. In other words, soybean meal and urea provided the supplemental protein in various ratios of 100:0, 67:33, 33:67, and 0:100.

Feedlot performance of the calves for the first 65 days is shown in Table 14.4. Gain and efficiency of feed conversion were progressively and significantly improved when an increased proportion of the supplemental protein came from soybean meal. Steers fed increased levels of urea tended to consume less total dry matter. Generally, one can expect the depressing effect of high-urea supplements on new cattle to persist for only about 2 weeks; after 2 weeks of adaptation, feedlot cattle are able to handle high-urea supplementation adequately.

Since adjustment of the rumen to urea utilization undoubtedly represents considerable stress, it is recommended that urea supplementation be replaced with natural protein supplements for newly received calves.

South Dakota research (Embry, 1977) essentially confirmed the earlier Ohio data (Table 14.5). The South Dakota cattle were fed prairie hay plus 2 lb (0.91 kg) of a 40% protein supplement containing either soybean meal or urea as a source of supplemental protein.

TABLE 14.4

Influence of Soybean Meal and Urea as Supplemental Protein Source on the Performance of New Feeder Calves[a]

	Source of supplemental protein							
	All soybean meal		2/3 soy 1/3 urea		1/3 soy 2/3 urea		All urea	
	lb	kg	lb	kg	lb	kg	lb	kg
Number of calves	16		18		18		18	
Initial weight	376	171	380	173	399	181	393	179
Final weight	547	249	542	246	539	245	529	240
65-day gain	171	78	162	73	140	64	136	61
Daily gain	2.63	1.2	2.49	1.1	2.15	1.0	2.09	0.95
Daily feed								
Corn silage	29	13	28	13	27	12	27	12
Supplement	2	0.9	2	0.9	2	0.9	2	0.9
Dry matter/unit gain	4.6		4.8		5.3		5.5	

[a]Anonymous (1975).

E. Protein Level Effect on New Feedlot Cattle

The daily intake of protein is of major importance for new feedlot cattle and is required in relatively large amounts, compared to other nutrients. The body is not able to store more than token quantities of protein. Thus, unless intake is ade-

TABLE 14.5

Urea Utilization with Prairie Hay during Adaptation Phase of 37 Days[a]

	Type of supplement			
	Soybean meal		4% urea	
	lb	kg	lb	kg
Number of cattle	32		32	
Initial weight	422	192	422	192
Final weight	482	219	473	215
37-day gain	60	27	51	23
Daily gain	1.61	0.73	1.34	0.61
Daily feed	13.2	6.0	12.9	5.9
Feed/unit gain	8.2		9.6	

[a]Embry (1977).

quate, the body may become deficient in protein within a matter of a few hours—especially during times of stress. Protein-deficient animals tend to be more prone to infection. South Dakota research (Embry, 1977) demonstrated the effect of adequate supplemental protein on the performance of new feeder calves.

Feeding diets containing more than 13.5% protein, on a total dry matter basis, appeared to have little benefit. The 13.5% protein translates over to approximately 12% protein on an "air-dry" (85% dry matter) basis. A diet containing 10.5% protein was not adequate. Note from Table 14.6 that the level of dietary protein did not affect total dietary dry matter consumption.

F. Preconditioning Feeder Cattle

The inclusion of this topic is largely for theoretical purposes because although a good preconditioning program has a very positive effect on cattle about to be shipped, it seems that nobody "is willing to pay for it." Preconditioning, in its simplest definition involves the weaning process, coupled with conditioning shots and feed initiation. This can require up to 4 or 5 weeks. "Conditioned" calves then are shipped either to sales barns for auction or to their next feeding destination.

In a preconditioning program, cattle usually are wormed, grubbed, deloused, implanted with growth stimulant, castrated, spayed, branded (if desired), and given a variety of shots—at least an IBR (infectious bovine rhinotracheitis) shot and injections of vitamins A and B_{12}.

G. Preconditioned Calves—Do They Do Better?

This is a question that is extremely difficult to answer in summary form. One can present data to demonstrate both positive and negative answers to this question. If an operator has little or no morbidity and/or death loss in newly purchased feeder cattle which have not been preconditioned year after year, it is pretty difficult to convince such an operator that a premium should be paid for preconditioned feeder cattle.

The Purdue University Veterinary Science and Animal Science Departments cooperated with comparable departments at Oklahoma State University (Meyer *et al.*, 1971) in working with Oklahoma calves which were shipped to the Purdue University feedlots. Four general treatments were imposed on the Oklahoma cattle prior to shipment: (1) those weaned and shipped the same day; (2) those weaned 30 days prior to shipment and placed on hay, grain, and supplement; (3) those vaccinated with BVD, IBR, and parainfluenza-3 vaccine approximately 45 days before shipment, but weaned and shipped the same day; and (4) those treated as in group (3) above, but weaned 30 days prior to shipment and fed as listed in group (2) above.

TABLE 14.6

Levels of Protein Supplementation on Feedlot Adaptation of New Feeder Calves—29 Days[a]

	Percentage of protein in the diet			
	10.5	13.5	16.5	19.5
Number of cattle	19	19	19	19
Initial weight				
lb	374	374	373	375
kg	170	170	170	170
Daily gain, cumulative				
7 days				
lb	1.9	2.8	2.5	2.7
kg	0.86	1.27	1.14	1.22
14 days				
lb	1.9	2.5	2.3	2.7
kg	0.86	1.14	1.04	1.22
21 days				
lb	2.4	2.7	2.6	3.0
kg	1.09	1.22	1.18	1.36
28 days				
lb	2.2	2.4	2.3	2.5
kg	1.0	1.09	1.04	1.14
Daily feed, by period				
7 days				
lb	10.4	10.2	10.1	10.9
kg	4.7	4.6	4.6	5.0
14 days				
lb	10.7	10.8	10.9	11.1
kg	4.9	4.9	5.0	5.0
21 days				
lb	12.1	12.3	12.3	12.6
kg	5.5	5.6	5.6	5.7
28 days				
lb	13.7	14.0	13.0	14.4
kg	6.2	6.8	5.9	6.5

[a]Embry (1977).

How do preconditioned calves perform compared to nonpreconditioned ones? Note from Table 14.7 that preconditioned or vaccinated calves started more rapidly (see first 28-day performance), but by the end of the total feedlot life (252) days, no differences existed in feedlot performance between preconditioned and nonpreconditioned calves. Based on these data it would seem doubtful that preconditioning practices could be justified on a year-to-year basis. Rather, it

TABLE 14.7

Feedlot Performance of Weaned versus Nonweaned, and Vaccinated versus Nonvaccinated Feeder Cattle[a]

	Treatment			
	Weaned	Nonweaned	Vaccinated	Nonvaccinated
Number of steers	72	71	72	71
First 28 days after shipment				
Initial weight				
lb	453	436	445	443
kg	206	198	202	201
28-day weight				
lb	534	502	521	514
kg	243	228	237	234
Gain/animal				
lb	81	66	76	71
kg	37	30	35	32
Daily gain				
lb	2.89	2.35	2.71	2.54
kg	1.31	1.07	1.23	1.1
Total 252-day performance				
252-day weight				
lb	992	975	991	976
kg	451	443	450	443
Gain/animal				
lb	539	539	546	533
kg	245	245	248	242
Daily gain				
lb	2.14	2.14	2.16	2.12
kg	0.97	0.97	0.98	0.96

[a]Meyer *et al.* (1971).

should be viewed as a type of disaster insurance. Similarly, the performance of vaccinated and nonvaccinated calves was similar. However, in a disaster type year disease might wipe out a large number of calves and the net effect of prolonged morbidity might affect the calves their entire feedlot life. In the case of vaccination in the test research, it was not anticipated that it would affect feedlot performance of the cattle on test. A vaccination program is executed to save lives and probably will have little or no effect on the performance of those that survive. Naturally, there will be exceptions to this observation. For example, cattle which have a rather prolonged siege of respiratory infections may be delayed in starting the feedlot experience; occasionally such cattle may develop adhesions of the lung wall to the chest cavity.

It may be of interest to note how feeder cattle buyers respond to various types of preconditioning. Turner *et al.* (1992) summarized the sale of 1368 lots of cattle (95,930), from 1977 to 1988, through the Georgia teleauctions in that state. The following are six responses of purchasers to various aspects of preconditioning: (1) cattle which had been treated for external parasites were discounted—this was baffling at first, but then the authors concluded the purchasers might suspect other problems; (2) purchasers discounted cattle which had been dewormed; (3) a slight premium was paid for cattle which had been implanted with growth hormone; (4) cattle which had been vaccinated for specific diseases (IBR, BVD, etc.) brought a significant premium; (5) horned cattle which had been dehorned brought a premium; (6) feeder cattle which had been through a preconditioning program did bring a significant premium.

H. Backgrounding Feeder Cattle

Backgrounding (Hendrix and Smith, 1975) can be contrasted to preconditioning primarily by the length of time involved. Whereas a preconditioning program runs 21 to 35 days, a backgrounding program may last for 6 or 7 months, or even longer. The backgrounding phase includes the time lapse between weaning and when the cattle enter the feedlot to be finished for slaughter. Backgrounded calves may gain from 100 to 400 lb (45 to 180 kg), depending upon the diet fed and the length of the backgrounding program.

Backgrounding of more than a month or two becomes the same as the Stocker Program, discussed in Chapter 15.

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15

Feeding Stocker Cattle

Tilden Wayne Perry

A stocker is a young beef animal fed to grow but not to improve its general condition of flesh. In other words, a stocker that gains 100 pounds (45 kg) over a given period of time would be in the same degree of finish at the end of the period as it was when it started such a feeding program. There are two general types of stockers—heifers grown for replacement, and steers grown for subsequent fattening. If sufficient minerals and vitamins are available, it is possible to limit the rate of gain of immature beef cattle by limiting either the protein or the energy made available to them. However, it is far more desirable to limit gain by limiting the energy fed than by limiting daily protein allotment since the latter technique might conceivably exert a permanent undesirable effect on the animal.

Stocker growth is nourished, normally, with a preponderance of roughages, balanced with adequate protein, minerals, and vitamins. Unless subsequent programs will limit gains markedly, stockers should be fed to gain from 0.9 to 1.5 lb per head, daily (0.41 to 0.68 kg/day). With any less gain, the overhead cost will be prohibitive; with any greater gain, cattle will come out of the stocker program carrying too high a degree of finish. A "too fat animal" coming off a stocker program can be expected to have depressed performance during the finishing phase.

I. FEEDING PROGRAMS FOR STOCKERS

A. Hay Program

Many stocker programs are conducted in drylot when pasture is scarce (Fig. 15.1). Thus, the feeding of harvested roughages is most common. Naturally, hay can vary so greatly in quality that it is dangerous to generalize on a specific feeding program. However, if medium-quality hay is available, a typical consumption of 12 to 18 lb (5.4 to 8.2 kg) of such hay should cause stocker cattle to gain from 0.75 to 1.00 lb per day (0.34 to 0.45 kg/day). It is quite likely that

Fig. 15.1 High-quality grass–legume hay fits well into drylot cattle feeding. (Photo courtesy of BEEF Magazine.)

there will be adequate protein for normal growth since "average" quality grass–legume hay contains upward of 12–15% protein, and a growing stocker requires only 10 to 11% protein. With adequate minerals (free choice mineral mixture of 3 parts dicalcium phosphate:1 part trace mineralized salt) along with an intramuscular injection of 2.5 million IU of vitamin A, initially, stockers' nutrient needs could be met adequately. Use of a growth hormone implant will give an economical additional boost in growth. This program should cause healthy stocker cattle to gain over 1.00 lb per day (0.45 kg). If it is desirable to elevate the rate of gain an additional third of a pound per day (0.15 kg), the feeding of an additional 4 lb (1.8 kg) of concentrates per head daily can be added to the hay program.

B. Cornstalk Pasture Program

Well-matured weanling calves can do pretty well on cornstalk fields as long as feed is ample. However, cornstalk leaves and husks primarily provide energy, so additional protein, minerals, and vitamin A will be needed. This can be provided by feeding a minimum of 3 lb (1.36 kg) of legume hay per day, scattered on the ground—5 or 6 lb (2.3–2.7 kg) of legume haylage will accomplish the same goal. Also, a good free choice mineral mixture, as listed above, will be adequate. At the start of this program, inject the cattle with 2.5 million IU of vitamin A, intramuscularly, and implant a growth-stimulating product. The cornstalk pasture program will not support much better gain than 0.8 lb/day (0.36 kg), but the gain will be perhaps more economical than that on the hay program listed above.

A well-formulated free choice liquid supplement offered in a lick tank works well in this program, allowing the cattle to more nearly meet their protein, mineral, and vitamin needs.

C. Winter Range

In certain parts of the country, calves are "overwintered" on winter range or pasture to be sold as short yearling feeder cattle the next spring. Unless some supplemental protein and/or energy plus minerals and vitamin A are provided, such calves do little more than remain stable on such program. Naturally, the performance on this program is related to pasture quality plus whatever supplemental program is pursued. However, such programs can be justified in order to hit a higher spring market than might have been realized from a fall sale of the calves.

D. Silage Program

It is most difficult to administer a corn silage or sorghum silage feeding program that will limit the gains of calves to no more than 1.5 lb (0.68 kg) per day because both types of silage are classified as "high-energy" roughages. Both types of silage are deficient in protein for stocker calves, so when either silage is fortified with protein and minerals, it is most difficult to limit gain to in excess of 2 lb (0.90 kg) per day, which is too rapid a rate of gain for stocker cattle. The only control of energy, then, is to limit the daily intake of the silage.

E. Winter Wheat Pasture

Many years ago wheat producers of the Great Plains area of the United States learned they could safely pasture off the winter growth of fall-sown wheat. In fact, the grazing process helped the wheat plants to spread out, and was actually

beneficial to the wheat growing program. As a result, shipment of stocker cattle for many miles to overwinter on wheat pasture has become a common practice and a profitable business for both cattlemen and wheat growers. Thrifty calves should gain 1 to 1.5 lb/day (0.45 to 0.68 kg) on good wheat pasture. Probably the only supplemental nutrients needed on the wheat pasture are free choice minerals.

F. Summer Pasture Program

The performance one can expect from healthy stocker cattle on a summer pasture program is correlated highly to pasture quality. Herein the word "quality" refers not only to the predominant pasture crops grown, but also to the condition of growth of the pasture. In other words, pasture quality can range all the way from the epitome of lush young growth of palatable grass–legume mixtures down to a woody, droughty vegetation that has very little growth potential even when cattle can find it and are willing to consume it. Therefore, it is most difficult to predict performance from a summer pasture program without pinpointing all of the specifics. As a good example of this, typically in the Corn Belt or Midwestern United States, it is common to consider that stockers grazing Kentucky bluegrass–bromegrass mixtures will make two-thirds of their growth on summer pasture during the first one-third of the pasture season. Thus, under these conditions it is necessary to consider whether some concentrates should be fed to stocker cattle on pasture starting around July 15, rather than staying with declining performance on pasture alone from mid-July to the time of the killing frosts (November 1).

II. CONTROLLED GROWTH OF STOCKERS

Earlier it was implied that the growth of stockers could be controlled by the level or concentration of energy available to them. It is not possible to give an exact formula for predicting a specific gain because different types of cattle are involved. Furthermore, if genetics was ruled out, feedstuffs bearing the same name will vary considerably in quality. Nevertheless, it is possible to approximate diet formulation for cattle to gain at a predetermined rate. The National Research Council tables on predicted performance are extremely valid; if these conditions are followed, performance will be quite close to what the tables predict.

In 1958, researchers at the Miller–Purdue Agricultural Center conferred with Purdue University animal scientists to formulate diets for stocker calves which would cause four groups of calves to gain 0.5, 1.0, 1.5, and 2.0 lb/per day, respectively (0.23, 0.45, 0.68, and 0.90 kg), over a 140-day period (McVey *et*

TABLE 15.1

Diets for Causing Stocker Steer Calves to Gain at Various Rates (4 Years)[a]

	Desired daily gain over 140 days			
lb:	0.5	1.0	1.5	2.0
kg:	0.23	0.45	0.68	0.91
Ingredient per day				
Ground corn cobs				
lb	9.0	7.0	5.0	—
kg	4.1	3.2	2.3	—
Corn silage				
lb	—	9.0	14.5	30.5
kg	—	4.1	6.6	13.9
32% cattle suppl.[b]				
lb	1.5	1.5	3.0	3.5
kg	0.68	0.68	1.36	1.59
Actual performance by years, daily gain				
Year 1				
lb	0.58	1.06	1.69	2.14
kg	0.26	0.48	0.77	0.97
Year 2				
lb	0.48	1.00	1.50	2.01
kg	0.22	0.45	1.02	0.91
Year 3				
lb	0.52	0.97	1.53	1.86
kg	0.24	0.44	0.70	0.84
Year 4				
lb	0.61	0.94	1.42	1.85
kg	0.28	0.43	0.65	0.84
Average				
lb	0.55	0.99	1.54	1.96
kg	0.25	0.45	0.74	0.89

[a]McVey *et al.* (1958).
[b]32% protein supplement fortified with vitamin A, dehydrated alfalfa meal, dicalcium phosphate, salt, and cobalt.

al., 1958). The cattle utilized were weanling Hereford steers purchased from the Great Plains area. The study was repeated for four winters, starting in December and ending 140 days later for each of the 4 years. It is interesting to note how accurately gains can be predicted for cattle utilizing the latest National Research Council Tables. (Note the 4-year averages presented in Table 15.1.)

Table 15.2 presents variations of formulas, based on the National Research Council recommendations, for predicting various rates of gain for stocker cattle.

TABLE 15.2

Suggested Winter Diets for Growing 400- to-500-lb (180–227 kg) Stocker Cattle

	Dietary ingredient, per head, daily							
	1	2	3	4	5	6	7	8
Daily gain								
lb	0.5	0.5	0.75	1.0	1.0	1.0	1.25	1.25
kg	0.23	0.23	0.34	0.45	0.45	0.45	0.57	0.57
Grass hay, late cut								
lb	13							
kg	5.9							
Gr. corn cobs								
lb		11				8		
kg		5.0				3.6		
Grass–legume hay, early cut								
lb			13				11	
kg			5.9				5.0	
Legume hay, early cut								
lb				13				
kg				5.9				
Cornstalk silage (65% moisture)								
lb					33			
kg					15			
Corn silage (65% moisture)								
lb						12		33
kg						5.4		15
Corn grain								
lb							3.5	
kg							1.6	
32% protein suppl.[a]								
lb	1	2			2	2		2
kg	0.45	0.91			0.91	0.91		0.91
Mineral mixture[b,c]	FC	FC	FC	FC	FC	FC	FC	FC

[a]The supplement should contain 15,000 IU vitamin A/lb (33,000IU/kg).
[b]Two parts dicalcium phosphate and one part trace mineralized salt.
[c]FC, free choice.

III. WINTER GAIN EFFECT ON SUMMER PASTURE GAIN

As a follow-up to the winter gain of stocker calves, the effect of such gain on summer pasture gains of nonyearling stocker steers was studied. In other words, pasture gain studies were conducted during each of the four summers following the previous 140-day winter studies. Beef production on alfalfa–grass pastures

TABLE 15.3

Effect of Previous Winter Gain on the Subsequent Gain of Stocker Cattle on Pasture[a]

		Previous 140-day winter daily gain			
Grazing season	Number of days	0.5 lb (0.23 kg)	1.0 lb (0.45 kg)	1.5 lb (0.68 kg)	2.0 lb. (0.91 kg)
Year 1	140	1.49 lb	1.18 lb	0.88 lb	0.79 lb
		0.68 kg	0.54 kg	0.40 kg	0.36 kg
Year 2	168	1.24 lb	1.08 lb	0.97 lb	0.67 lb
		0.56 kg	0.49 kg	0.44 kg	0.30 kg
Year 3	189	1.13 lb	1.05 lb	0.66 lb	0.70 lb
		0.51 kg	0.75 kg	0.30 kg	0.32 kg
Year 4	140	0.98 lb	1.01 lb	0.80 lb	0.50 lb
		0.44 kg	0.46 kg	0.36 kg	0.23 kg
Average		1.21 lb	1.08 lb	0.83 lb	0.66 lb
		0.55 kg	0.49 kg	0.38 kg	0.30 kg

[a]McVey *et al.* (1958).

over the summer was studied for each group for each of the 4 years. The average daily gain on pasture alone was affected by the previous winter's gain (Table 15.3). In fact, cattle which had gained approximately 0.5 lb/day(0.23 kg) the previous winter gained nearly double the rate on pasture of cattle which had gained 2.0 lb/day (0.91 kg) the previous winter (1.21 versus 0.66 lb/day; 0.55 versus 0.30 kg).

IV. PASTURE MANAGEMENT EFFECT ON STOCKER PERFORMANCE

Stocker cattle often are turned to pasture without much regard for optimal management of the pasture. But then one must consider whether it would pay to fertilize the pasture lands, or whether it would pay to rotationally graze pasture areas. Research was conducted at the Miller–Purdue Agricultural Center (Mott *et al.*, 1948) to compare stocker beef performance on pastures which were fertilized, limed, and rotationally grazed. Also, a comparison was made on a fertilized pasture containing birdsfoot trefoil in addition to the permanent bluegrass plants.

The data in Table 15.4 answer questions posed in the above paragraph. For example, the addition of 300 lb (136 kg) of 0–20–10 fertilizer, coupled with rotational grazing, resulted in a 47% increase in beef production per area of pasture, or an extra 71 lb/acre (80 kg/ha) of beef. (Previous research had indicated no benefit from rotational grazing on nonfertilized pasture.) The addition of

TABLE 15.4

Pasture Treatment Effect on Stocker Beef Production[a]

Bluegrass pasture type	No. steers per		Daily gain		Gain per steer		Beef produced (lb per)	
	acre	ha	lb	kg	lb	kg	acre	ha
1. Permanent, no fertilizer, continuous graze	0.93	2.3	1.14	0.52	169	77	150	370
2. 300 lb (136 kg) 0-20-10, permanent, rotation graze	1.40	3.4	1.13	0.52	159	72	221	546
3. 300 lb (136 kg) 0-20-10, 200 lb (91 kg) ammonium nitrate, rotation graze	2.09	5.2	0.81	0.37	112	51	237	586
4. Same as 3. (above), not grazed, July 12–Sept 9 (deferred grazing)	2.55	6.3	1.61	0.73	139	63	346	855
5. Birdsfoot trefoil mixed in bluegrass 300 lb (136 kg) 0-20-10, rotation graze	2.29	5.6	1.03	0.47	123	56	334	825

[a]Mott *et al.* (1948).

ammonium nitrate (treatment 3) did not contribute too much to the nutritional value of the grazing.

Deferred summer grazing, or holding cattle off pasture during the summer drought period, resulted in a further 56% increase in total stocker production (treatment 4 versus treatment 2). Inclusion of birdsfoot trefoil (a legume plant) resulted in a 51% increase in stocker per acre over fertilized pasture not containing the legume (treatment 2).

V. GRAIN FEEDING LEVELS ON PASTURE

Research at Purdue University (Perry *et al.*, 1972) has shown the effect of feeding various levels of concentrates to stocker cattle on pasture. This study covered 4 years (four experiments) of pasture studies. As a follow-up to the pasture trials discussed above, all cattle were finished out to a slaughter finish to determine the effect of summer pasture gains on subsequent fattening gains. The pasture phase averaged 135 days in length (May 6 to September 8) and the pasture or drylot fattening phase extended from an average of 52 to 124 days. The criteria for termination of the drylot finishing phase were reaching USDA Choice and as close to 1100–1150 lb (500–523 kg) liveweight as possible. The

levels of concentrate fed on pasture which were compared were (1) no concentrate, (2) one-third full feed of concentrates, (3) two-thirds full feed of concentrates, and (4) a full feed of concentrates during the entire pasture period. In addition, (5) a "control" group was fed a full feed of concentrates in drylot from the start of the pasture season until they reached market finish and grade.

The concentrates fed consisted of 8 parts ground ear corn to 1 part of a complex 32% protein supplement (Purdue Supplement A), mixed together. The pasture crop was a legume–perennial grass mixture. The drylot phase for the cattle started on September 18, when they were moved alongside group 5 which had been in drylot throughout the entire experiment each year. From the two full-fed lots—one on pasture and one in drylot—it is possible to calculate how much the pasture contributed (or how much concentrate was saved).

From Table 15.5 note that full-fed cattle on pasture required 6.4 lb (2.91 kg) of concentrate per pound of gain, whereas those in drylot required 7.6 lb (3.45 kg), or 1.2 lb (0.45 kg) more. Therefore, gain per steer (full-fed on pasture) was 393 lb (179 kg) × steers per acre (4.9) (12 steers/ha) × feed saved per pound

TABLE 15.5

Effect of Level of Grain Fed on Pasture on Rate of Gain of Stocker Steers, May 6 to September 18, 135 Days (4 Years)[a]

	Percentage of full feed of grain fed on pasture				Drylot control
	0	33	67	100	
Initial weight					
lb	638	612	625	634	616
kg	289	278	284	288	280
Ending weight					
lb	759	878	933	1027	1025
kg	345	399	424	467	466
Daily gain					
lb	0.95	1.84	2.36	2.94	3.03
kg	0.43	0.84	1.07	1.34	1.37
Steers/area					
Acres	1.7	2.0	2.9	4.9	—
Hectares	4.2	4.9	7.2	12.1	—
Concentrates consumed/day					
lb	0	6.2	12.5	18.7	22.9
kg	0	2.8	5.7	8.5	10.4
Concentrates per steer					
lb	0	832	1694	2526	3089
kg	0	378	770	1148	1404
Concentrates per unit of gain	0	3.1	5.5	6.4	7.6

[a]Perry *et al.* (1972).

TABLE 15.6

Finishing Phase of Pasture Concentrate Level of Feeding, September 18 to Finish (4-Year Summary)[a]

	Level of concentrate fed previously on pasture (percent of full feed)				Drylot control
	0	33	67	100	
Weight, end of pasture					
lb	759	878	933	1027	1025
kg	345	399	424	467	466
Drylot daily gain					
lb	2.82	2.54	2.28	2.28	1.74
kg	1.28	1.15	1.04	1.04	0.79
Daily concentrates					
lb	23.8	23.8	24.2	24.0	24.2
kg	10.8	10.8	11.0	10.9	11.0
No. days in drylot phase	124	110	98	57	46
Concentrates, both phases					
lb	2941	3456	4083	3777	4200
kg	1337	1571	1819	1717	1909
Total gain per steer, both phases					
lb	475	543	537	510	491
kg	216	247	244	232	223
Concentrates per steer gain	6.2	6.4	7.6	7.4	8.6

[a]Perry *et al.* (1972).

gain, compared to those in drylot, or 1.2 lb (0.54 kg), would equal 2310 lb of concentrate saved per acre of pasture (1160 kg/ha of pasture).

Table 15.6 shows the effect of previous summer pasture gain of stocker cattle on their performance in drylot. Gains in the drylot finishing phase were correlated negatively ($r = -0.96$) with previous pasture gain. For each additional 10 lb (4.5 kg) the stocker grew on pasture, it gained 1.3 lb (0.59 kg) less in the finishing phase.

VI. STOCKER RESPONSE TO MONENSIN SODIUM ON PASTURE

In July, 1978, The Food and Drug Administration cleared monensin sodium (Rumensin) as a growth stimulant for use with cattle on pasture. However, it was approved with certain legal restrictions (namely, it must be fed in a minimum of 1 lb per animal daily (0.45 kg) at a dose range of 50 to 200 mg Rumensin per head. The matter of 1 lb of feed per head, daily, may present some problems in administering Rumensin. However, the use of a free choice lick tank to provide

the cattle supplement helps to solve this problem. Naturally, the prescribed dosage of Rumensin would be suspended in the liquid supplement.

Brown (1978) summarized 23 pasture experiments in which Rumensin fed for an average of 125 days to calves weighing 500 lb (227 kg) at the start resulted in a 15% increase in gain. Normally, in drylot on higher energy diets, cattle gain similarly with and without Rumensin. However, Rumensin-fed cattle eat about 10% less feed per day, so that at the same rate of gain on 10% less feed consumed, Rumensin-fed cattle are 10% more efficient. On pasture, cattle fed rumensin consistently gain more rapidly. In the research summary referred to above, control cattle gained an average of 1.32 lb/day (0.6 kg), whereas those fed Rumensin gained 1.52 lb/day (0.69 kg). Thus in 125 days, Rumensin feeding resulted in an extra 25 lb (11.36 kg) of stocker beef. The propionic acid increase appeared in the 23 pasture studies, averaging 19.3 molar percent in control cattle and 24.2 molar percent in Rumensin-fed cattle, or a 25% increase in propionic acid produced.

It has been suggested that on a high-energy diet, cattle eat to a caloric satiety; that is, they eat until they have absorbed sufficient calories from their diet. Thus a steer on a high-concentrate diet meets its caloric requirements on 10% less feed consumed when it is also fed Rumensin because of the increased production of propionic acid. On the other hand, cattle eating a high-roughage diet (low energy) would tend to consume more than their digestive tract will accommodate, in order to meet their caloric needs. Therefore, on a high-roughage diet, they consume the same amount of feed whether or not they receive Rumensin. Since the Rumensin provides 10% more energy, cattle fed a high-roughage diet plus Rumensin consume the same amount of feed and gain 10% faster.

Wherever it is possible to supply Rumensin in a minimum of 1 lb (0.45 kg) of feed to cattle on pasture, it is desirable to do so.

There are other ionophores on the market (Bovatec, Catalyst) which have an ultimate effect similar to that of Rumensin. It is not the intent of this text to recommend one commercial product over another and it is a matter of choice by the provider and the cattle feeder as to which trade product will be used.

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16

Cattle Finishing Systems

Tilden Wayne Perry

Cattle feeding tends to fall into one of a few categories. For instance, cattle purchased (or raised) are usually either calves or yearlings; they are of the type that will feed out to a U.S. government grade of Choice, Select, or Standard, and they are heifers or steers (castrated males)—and sometimes intact bulls (bullocks). Similarly, feeding program types are few in number in which only the pattern or timing of feeding high-energy and medium- or low-energy diets is manipulated. Wherever corn is grown successfully, many cattle feeders rely on corn (maize) and whole plant corn silage as the principal sources of energy, whereas in milo country, milo will supply most of the energy. In barley country, barley is the main source of beef cattle high energy feedstuff. In other words, beef cattle are so well adapted to respond to almost any wholesome source of energy that supplying higher-energy diets to them consists of deciding which source is most economical and most convenient. As energy programs are presented in this section it should be borne in mind that one energy source may be replaced by almost any other equivalent source without affecting feedlot performance.

A cattle feeding system is defined as a feeding enterprise for which the animal's sex, grade, and starting and finishing weights have been specified. In fact, we have learned how to predict these results so well that it is possible to sell cattle on the futures market, predicting within ±15 days when the cattle will be ready for market at a specified weight and grade. Naturally such factors as environment and an unpredicted disaster of some sort can change this predictability.

Table 16.1 summarizes the most common systems of finishing cattle but does not include growing or stocker programs. Rather, it takes up at a point where wintering or summer pasture stocker programs leave off, and whereby cattle are fed rather highly concentrated diets for the remainder of their feedlot life so they will reach the desired weight and slaughter finish. The starting weight is the weight of the animal after it has arrived at the feedlot; the finishing weight is the weight at which the animal is about to be sold. All systems described and detailed in the following programs are designed to start at the point when the initial health conditioning period of 2 to 4 weeks is completed. Admittedly the

TABLE 16.1

Feedlot Finishing Systems

USDA grade	Age	Sex	Starting weight		Finishing weight		Daily gain		Days on feed
			lb	kg	lb	kg	lb	kg	
Choice	Calf	Steer	550	250	1100	500	2.8	1.3	200
	Calf	Heifer	500	227	950	432	2.7	1.2	175
	Yearling	Steer	700	318	1200	545	3.3	1.5	150
	2 years	Steer	800	364	1200	545	3.3	1.5	135
Select	Calf	steer	500	227	1100	500	2.8	1.3	210
	Yearling	Steer	700	318	1150	522	3.3	1.5	150
	2 years	Steer	800	364	1200	545	3.3	1.5	120
Standard	Yearling	Steer	700	318	1100	500	2.9	1.3	140
	2 years	Steer	800	363	1200	545	2.9	1.3	140

programs are based on corn and corn silage, but these are meant to be prototypes for which other feedstuffs may be substituted freely on the basis of price per unit of energy.

I. CHARACTERISTICS OF CATTLE FINISHING SYSTEMS

A. Choice Grade

1. Steer Calf

This is a quality type animal which can carry a relatively high degree of finish (fat cover). It can produce one of the most popular carcasses for the chainstore grocery trade. The Choice steer calf does not have the time nor capacity to be subjected to very great quantities of corn silage except for a very short time initially. To take advantage of maximum performance, the steer calf is implanted with recommended and approved growth stimulants, initially and at least one time more, or in accordance with the recommendation of the manufacturer of such products. It is important that such recommendations be followed explicitly. Such an animal should be ready for market at 1050 lb (477 kg), after having been in the feedlot for 180 to 210 days with an average daily gain of 2.8 to 3.2 lb (1.3–1.4 kg) (Table 16.2).

2. Heifer Calf

Rations for a heifer calf should contain a high proportion of concentrates and a low proportion of corn silage, since it is critical to cause a heifer to reach slaughter weight and finish as rapidly as possible. However, the heifer should be

TABLE 16.2

Detailed Feeding Programs: Choice Steer Calf [Gain 550 lb (250 kg), 200 days, 2.8 lb/day (1.3 kg)]

	Consumption, daily					
	First 65 days		Second 65 days		Last 70 days	
Roughage program	lb	kg	lb	kg	lb	kg
1. Corn silage	20	9.1	18	8.2	12	5.4
Corn	5	2.3	7	3.2	16	7.3
High-urea suppl.	1	0.45	1	0.45	1	0.45
2. Corn cobs						
Ground ear corn (4 shelled corn:1 cob)[a]	14	6.4	18	8.2	24	10.9
High-urea suppl.	1	0.45	1	0.45	1	0.45
3. Haylage						
Haylage	20	9.1	15	6.8	12	5.5
Corn[a]	8	3.6	13	5.9	18	8.2
High-urea suppl.	0.5	0.22	0.5	0.22	0.5	0.22

[a] Where high moisture corn is to be used, increase the figures by 14%.

on the high-energy program sufficiently long that her carcass will grade U.S. Choice. The most reasonable growth stimulants should be administered to encourage maximum growth and finish. In order to reach the Choice grade, she will need to gain 400 to 450 lb (180–205 kg), at a rate of 2.5 to 2.8 lb/day (1.1–1.3 kg), requiring 160 to 180 days (Table 16.3).

TABLE 16.3

Detailed Feeding Program: Choice Heifer Calf [Gain 450 lb (205 kg), 175 days, 2.7 lb/day (1.23 kg)]

	Consumption, daily			
	First 75 days		Last 100 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	12	5.4	12	5.4
Corn	12	5.4	16	7.3
High-urea suppl.	1	0.45	1	0.45
2. No roughage, 16 parts whole shelled corn:1 high-urea suppl.				
Shelled corn	17	7.7	20	9.1
High-urea suppl.	1	0.45	1.3	0.60

TABLE 16.4

Detailed Feeding Program: Choice Yearling Steer [Gain 500 lb (227 kg), 150 days, 3.3 lb/day (1.5 kg)]

	Consumption, daily			
	First 50 days		Last 100 days	
Roughage program	lb	kg	lb	kg
1. Corn silage	35	16	12	5.4
Corn	6	2.7	19	8.6
High-urea suppl.	1	0.45	1	0.45
2. Corn cob or hay				
Cobs or hay	10	4.5	6	2.7
Corn	8	3.6	22	10
High-urea suppl.	1	0.45	1	0.45
3. Cobs				
Ground ear corn	18	8.2	25	11.4
High-urea suppl.	1	0.45	1	0.45

3. Yearling Steer

This animal can utilize a fairly high proportion of corn silage in the ration early in the feedlot period. However, yearling steers should be fed a pretty heavily concentrated diet in order to take advantage of the tremendous growing and finishing potential it possesses. By feeding such a diet of predominantly concentrates, plus utilizing the most efficient program of growth implants, such cattle should gain close to 3.25 lb/day (1.5 kg) for 130 to 150 days (Table 16.4).

4. Two-Year-Old Steer

This steer has probably come from some other feedlot. It should be "pushed hard" all the way to market finish (Table 16.5). It should gain over 3 lb/day (1.4 kg) for 120 days to a finish weight of 1200 lb (545 kg).

B. Select Grade

1. Steer Calf

This calf should be allowed to make some early economical gains by feeding it a rather heavy level of corn silage. One can afford to keep this type animal for a little longer—perhaps for as long as 7 or even 8 months. Utilize growth implants in accordance with regulations, but be certain to use the maximum amount approved. Feed to a final weight of 1000 to 1100 lb (454–500 kg), at a gain rate of 2.8 lb/day (1.3 kg) (Table 16.6).

TABLE 16.5

Detailed Feeding Program: Choice 2-Year-Old Steer [Gain 400 lb (182 kg), 135 days, 3.3 lb/day (1.5 kg)]

	Consumption, daily			
	First 60 days		Last 75 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	35	16	15	6.8
Corn	10	4.5	22	10
High-urea suppl.	1	0.45	1	0.45
2. Corn cobs				
Ground ear corn	17	7.7	25	11.4
High-urea suppl.	1	0.45	1	0.45

2. Yearling Steer

Some corn silage provided early can fit into this feeding program. However, in order to keep this animal gaining rapidly, feed a fairly high level of concentrates. Utilize a sound growth stimulation program. This animal should gain 3 lb/day (1.4 kg) for 120 days, for a gain of 400–420 lb (180–190 kg) (Table 16.7).

TABLE 16.6

Detailed Feeding Program: Select Grade Steer Calves [Gain 600 lb (273 kg), 210 days, 2.8 lb/day (1.27 kg)]

	Consumption, daily					
	First 70 days		Second 70 days		Last 70 days	
Roughage program	lb	kg	lb	kg	lb	kg
1. Corn silage						
Corn silage	25	11.3	25	11.3	12	5.4
Corn	6	2.7	10	4.5	18	8.2
High-urea suppl.	1	0.45	1	0.45	1	0.45
2. Corn cobs or hay	12	5.4	10	4.5	8	3.6
Corn	6	2.7	10	4.5	20	9.1
High-urea suppl.	1	0.45	1	0.45	1	0.45
3. Self-feeder						
20 parts ground shelled corn						
4 parts ground hay or cobs						
1.5 parts high-urea suppl.						
The above mixture fed according to appetite.						

TABLE 16.7

Detailed Feeding Program: Select Grade Yearling Steer [Gain 450 lb (204 kg), 150 days, 3.3 lb/day (1.5 kg)]

	Consumption, daily			
	First 60 days		Last 90 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	35	16	12	5.4
Corn	8	3.6	24	10.9
High-urea suppl.	1	0.45	1	0.45
2. Cobs or hay: Total mixed ration				
20 parts ground shelled corn				
4 parts ground hay or cobs				
1.5 parts high-urea suppl.				
The above mixture fed according to appetite—it will average 25 lb/day (11.4 kg).				

3. Two-Year-Old-Steer

This may be a "warmed-up" steer with some fat already on it. This animal should be maintained on a minimum of corn silage and a full feed of corn. It should gain 3 lb/day (1.4 kg) for 120 days to a final weight of 1150 lb (523 kg) (Table 16.8).

TABLE 16.8

Detailed Feeding Program: Select Grade 2-Year-Old Steer [Gain 400 lb (182 kg), 120 days, 3.3 lb/day (1.5 kg)]

	Consumption, daily			
	First 60 days		Last 60 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	45	20	15	7
Corn	5	2.3	24	11
High-urea suppl.	1	0.45	1	0.45
2. Corn cobs or hay: Total mixed ration				
20 parts ground shelled corn				
4 parts ground hay or cobs				
1.5 parts high-urea suppl.				
The above mixture fed according to appetite.				

TABLE 16.9

Detailed Program: Standard Yearling Steer
[Gain 400 lb (182 kg), 140 days, 2.9 lb/day (1.31 kg)]

	Consumption, daily			
	First 90 days		Last 50 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	50	22.7	12	5.4
Corn	3	1.15	24	10.9
High-urea suppl.	1	0.45	1	0.45
2. Corn cobs or hay: Total mixed ration				
20 parts ground shelled corn				
4 parts ground cobs or hay				
1.5 parts high-urea suppl.				
The above mixture fed according to appetite				

C. Standard Grade

1. Yearling Steer

This animal probably has a high percentage of dairy breeding. There are two types of feeding programs that can be utilized—either a high-corn silage early, followed by a "hot" finishing ration to complete the program, or a hot ration for

TABLE 16.10

Detailed Feeding Program: Standard 2-Year-Old Steer
[Gain 400 lb (182 kg), 140 days, 2.9 lb./day (1.32 kg)]

	Consumption, daily			
	First 80 days		Last 60 days	
Roughage program	lb	kg	lb	kg
1. Corn silage				
Corn silage	55	25	12	5.4
Corn	3	1.4	28	12.7
High-urea suppl.	1	0.45	1	0.45
2. Corn cobs or hay: Total mixed ration				
20 parts ground shelled corn				
4 parts ground cobs or hay				
1.5 parts high-urea suppl.				
Feed the above according to appetite. Consumption will average 28 lb./day (12.7 kg).				

the entire feedlot period. This animal should gain 3 lb/day (1.4 kg) for 120 days, to a final weight of 1150–1200 lb (522–545 kg). Follow a good growth-stimulant program with these steers (Table 16.9).

2. Two-Year-Old Steer

This is probably a Holstein steer that has been grown on pasture or roughages. Use hormone implants and push this animal to the utmost to diminish its genetic tendency to develop a tremendous rumen. Such animals may gain from 3.25 to 4 lb/day (1.5–1.8 kg) for 120 days, for a final weight of 1250 to 1300 lb (545–590 kg). Unless one has had considerable experience feeding such animals, they should be sold by the time clock rather than gross appearance because appearance may be deceiving. Some of these cattle will grade U.S. Select, and a few will have sufficient marbling to make U.S. Choice (Table 16.10). Any of these carcasses that grade well are very attractive to restaurants and hotels because there is practically no fat cover over the loin eye.

Table 16.11 presents formulas for the high-urea supplements used in cattle feeding programs.

TABLE 16.11

Formulas for High-Urea Supplements

Ingredient	Percentage	Pounds per ton	Kilograms per metric ton
1. Purdue dry 64% supplement			
Urea (45% N)	20	400	200
Cane molasses	14	280	140
Dehydrated alfalfa meal (17% protein)	51	1020	510
Dicalcium phosphate	10.5	210	105
Iodized salt	3.5	70	35
Premix[a]	1	20	10
2. Purdue liquid 64% supplement			
Liquid urea (32%)	29	580	290
Cane molasses	38.5	770	385
Ammoniated polyphos (10-34-0)	9	180	90
Distiller's solubles (27% dry matter)	9.3	186	93
Salt solution (28% salt)	9	180	90
Calcium chloride	1.2	24	12
Sodium sulfate	1	20	10
Premix[b]	3	60	30

[a]Premix contributes, per ton, 40 million IU vitamin A, 2500 g zinc oxide, 8 g cobalt carbonate, 14 lb dehydrated alfalfa meal.

[b]Premix contributes 40 million IU vitamin A, 8700 g zinc sulfate, 19 g cobalt carbonate, 38 lb water.

II. SELF-FEEDING FINISHING CATTLE

Perhaps the most common method of feeding finishing cattle is to feed them according to their appetite, either once or twice daily. This method is almost necessary when high-moisture feedstuffs are a part of the diet in order to keep the feed fresh and to prevent mold and spoilage from building up in the feed trough. Usually the method of feed presented in this method of feeding (called hand-feeding), represents what the feeder anticipates the cattle will finish by the time the next feeding is due.

In the case of dry feed (85–90% dry matter), it is possible to feed cattle from self-feeders which need to be refilled only as often as the contents of the feeder are about to be depleted. Thus, only the capacity of the feeder—and the amount of feed the cattle are consuming—dictate how often additional feed should be added to the self-feeder (Figs. 16.1–16.3). Thus, conceivably, new feed is added only once or twice per week. However, the feedlot manager should inspect the feeding mechanism because almost any self-feeder can become clogged. Under such a situation, cattle could not have access to the feed intended for them until the situation is remedied.

Self-feeding of a balanced diet containing approximately 20% of roughage is practical and uncomplicated. In fact, cattle which have never been fed concen-

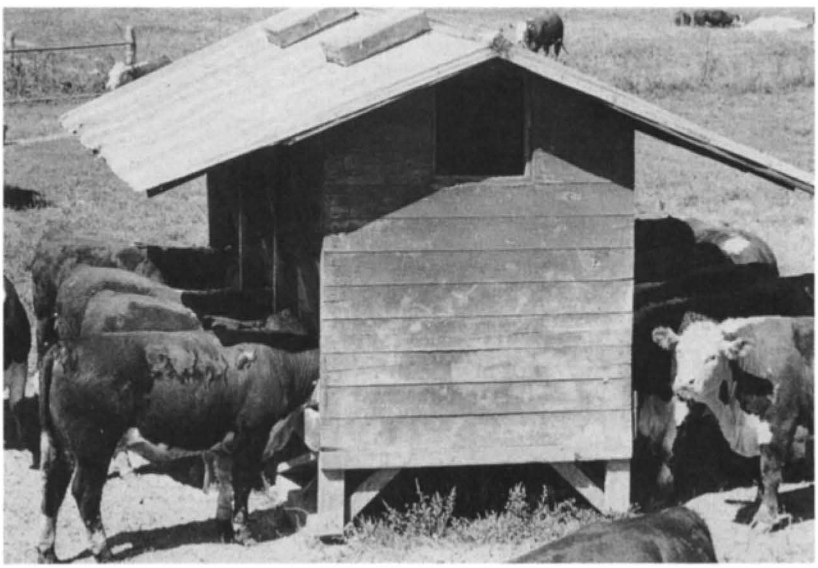

Fig. 16.1 Finishing cattle may be self-fed grain and minerals on pasture successfully. (Photo by J. C. Allen and Son.)

Fig. 16.2 Legal growth stimulants should be utilized with feeder cattle.

Fig. 16.3 Portable mixer trucks add flexibility to cattle feeding operations. (Photo courtesy of BEEF Magazine.)

trates before can be adapted to self-feeders on the first day without any harmful effects if the diet is formulated properly and mixed thoroughly. It is the purpose of this section to discuss self-feeding finishing cattle and to point out the safeguards which, when built in, will make self-feeding practical.

The research data shown in Table 16.12 are from cattle which were given access to a full feed of their respective diets on the very first day. There was no difficulty from looseness of bowels initially, or from foundering (advanced lactic acidosis) later on in the research, except for cattle fed a 12:1 ratio which contained 9.3% protein. Considerable looseness of bowel was observed among the cattle in that lot. Optimal performance at a reasonable consumption of protein supplement appeared to occur at a ratio of 8 parts ground ear corn to 1 part of a 32% protein supplement. Undoubtedly, cattle could be shifted to a leaner mixture of 10:1 or 12:1 as the feeding period progressed. However, for starting fresh cattle, a mixture of 8:1 has been used as a starting point in all feeding programs for many decades without encountering any problems.

TABLE 16.12

Self-Feeding Various Ratios of Ground Ear Corn and a 32% Protein Supplement for Finishing Cattle[a]

	Ratio of ground ear corn to a 32% supplement				
	4:1	6:1	8:1	10:1	12:1
Percentage protein	12.3	10.9	10.1	9.6	9.3
Number of steers	12	12	12	12	12
Initial weight					
lb	633	637	630	636	636
kg	287	289	286	289	289
Final weight, 195 days					
lb	1105	1143	1122	1111	1072
kg	502	520	510	505	487
Daily gain					
lb	2.42	2.60	2.53	2.44	2.24
kg	1.10	1.18	1.15	1.10	1.02
Daily feed					
Ground ear corn					
lb	16	19.2	19.2	18.8	18.6
kg	7.3	8.7	8.7	8.5	8.4
32% suppl.					
lb	4	3.2	2.4	1.9	1.5
kg	1.8	1.4	1.1	0.9	0.7
Crude protein per day					
lb	2.5	2.4	2.2	2.0	1.9
kg	1.1	1.1	1.0	0.9	0.9

[a]Perry *et al.* (1960).

Since the picker–sheller combine has made corn cobs unavailable for cattle feeding, one may ask what might be substituted for the cob portion if self-feeding is desired. Some other roughage such as hay or straw may be chopped and substituted. Another alternative which requires somewhat better management is to mix whole shelled corn with a pelleted 32% protein supplement, in a ratio of 9:1, and feed it along with free-choice hay or other roughage. Some care is needed in adapting cattle to this program, and it should require about 10 days to introduce new cattle to a full feed of the 9:1 mixture before they are allowed free access.

More recently, with the advent of higher protein supplements, it is possible to mix whole shelled corn and a pelleted 64% protein supplement together in a ratio of 16:1 and allow finishing cattle free access to a full feed after adjustment. Such adjustment means introducing them to the program gradually over 10 days, along with *ad lib* dry roughage to provide the rumen scratch factor (rumen tickling).

TABLE 16.13

Hand-Feeding versus Self-Feeding Shelled Corn versus Ground Ear Corn for Finishing Steer Calves, 216 days[a]

	Shelled corn		Ground ear corn	
	Hand-fed	Self-fed	Hand-fed	Self-fed
No. steers	20	20	20	20
Initial weight				
lb	467	466	467	466
kg	212	212	212	212
Final weight				
lb	968	990	947	967
kg	440	450	430	440
Daily gain				
lb	2.31	2.41	2.21	2.31
kg	1.05	1.10	1.00	1.05
Daily feed				
Corn				
lb	12.5	13.0	12.8	15.5
kg	5.7	5.9	5.8	7.0
32% suppl.				
lb	2.5	2.5	2.5	2.4
kg	1.1	1.1	1.1	1.1
Hay				
lb	4.2	3.5	3.7	3.4
kg	1.9	1.6	1.7	1.5
Salt to control supplement consumption		14 g (0.5 oz)		56 g (2 oz)
Feed per unit gain	8.3	7.9	8.6	9.3

[a]Perry *et al.* (1960).

Self-Feeding versus Hand-Feeding

How well can a feedlot manager judge the feed requirements as compared to allowing the animal to do the job? A good feedlot operator can come pretty close, but the feeder animal can probably do a slightly better job if it has access to a well-balanced formulation (Table 16.13). Under the conditions of this research self-fed cattle gained 0.10 lb/day (45 g) faster than hand-fed cattle. This small advantage probably resulted from the fact that the self-fed cattle were on a full feed from the first day whereas those on the hand-feeding program were brought up to a full feed of grain gradually.

Self-fed cattle have the option of regulating their own intake due to influence of their environment (such as changes in temperature, humidity, and atmospheric pressure) better than the feedlot operator is able to estimate. Perhaps hand-fed cattle do not make these adjustments as readily (Table 16.13).

Fig. 16.4 Even small feedlot operations can well afford a working chute with drop gates plus a squeeze chute.

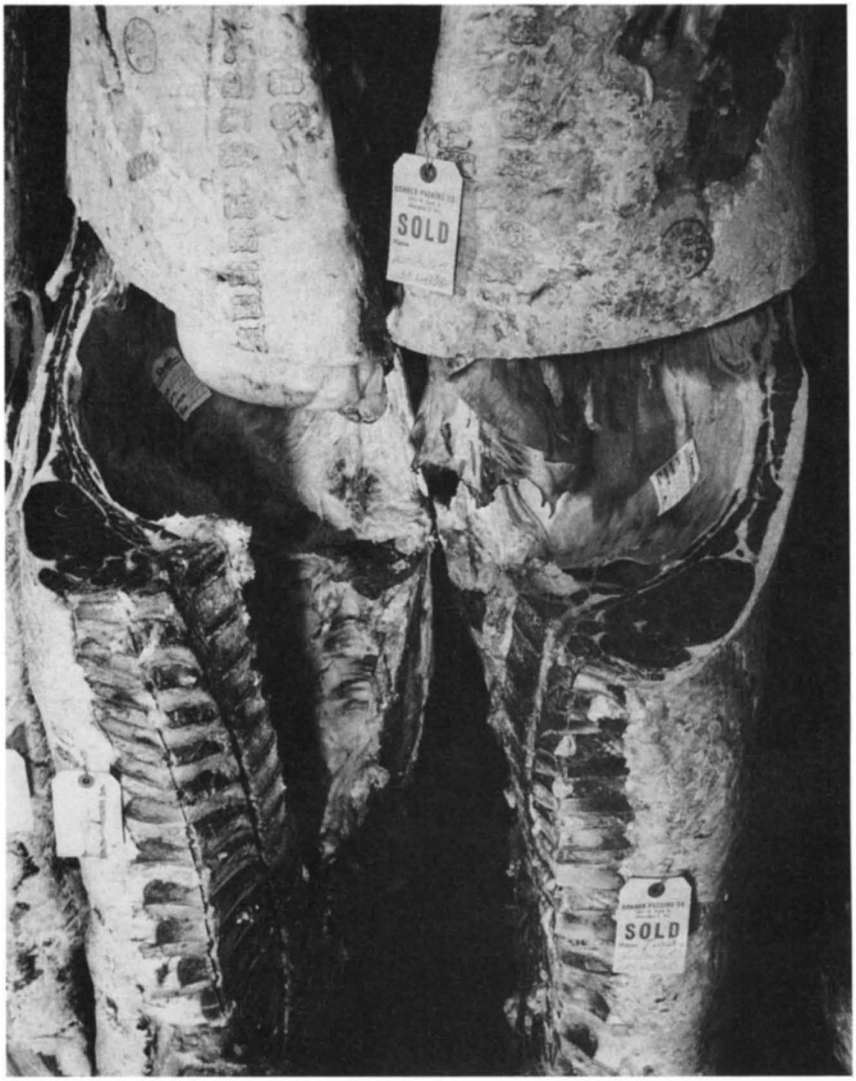

Fig. 16.5 United States Choice, yield grade 2 or 3 carcasses are the target for high quality beef. (Photo courtesy of BEEF Magazine.)

III. RECIPE FEEDING OF FINISHING CATTLE

Some feedlots will tend to follow a "recipe" approach to feeding finishing cattle. In this type of program, purchased cattle are virtually scheduled to a definite sale date, plus or minus a few days. This is particularly characteristic of

TABLE 16.14

Recipe Feeding: Diet Formulations for Feedlot Cattle[a]

Ingredient	Diet number (as is basis) %				
	1	2	3	4	5
Corn silage	50–60	40–50	25–30	18–23	6–8
Alfalfa pellets	5	5	7	7	7
Milo or corn	25–30	33–50	50–60	60–70	70–75
Wheat	0–5	0–5	0–10	0–10	0–10
Protein suppl. (40%)	5–7	5–7	4–7	4–7	4–7
Fat	0	0.5–1	2	2	2
Salt	0.5–1	0.5–1	0.5–1	0.5–1	0.5–1
Number of days	5–10 days	5–10 days	7–21 days	45 days	60 days

[a]Erickson and Phar (1970).

larger feedlots where overhead cost is fairly constant. Therefore, it is critical to move cattle in and out regularly so that the next group of cattle—already scheduled for purchase—may be able to move into the "just-vacated" pens (Figs. 16.4 and 16.5). Kansas State University researchers (Erickson and Phar, 1970) have developed such a set of recipes based on number of days in the feedlot. Five formulas are prepared (Table 16.14), and then each is fed for a specified number of days. The cattle are then advanced in energy content of their diet by switching to the next diet in the sequence for the specified number of days. The diets set up in the table are meant to be exemplary; naturally, an infinite number of combinations could be constructed, as well as appropriate substitutions made as price relationships per unit of nutrient content justifies it. However, these diets represent sound formulations for a 140-day feeding period for 700-lb (318-kg) steers to gain approximately 2.75 to 3.25 lb/day (1.25–1.5 kg), pay weight to pay weight.

IV. DIETS FOR SHOW CALVES

One can feed show calves quite similarly to other finishing cattle and such cattle will respond well if they have the genetic potential to do so. However, the basic tenet in show competition is how your animal places in its class. This section will not deal with genetics, selection of the calf, grooming, or showing. However, a formulation will be presented which puts together a combination of the very best nutrition ideas to give a slight edge necessary in a tightly contested race to take the purple ribbon. This diet has been used for fitting grand champion beef, so even though it is scientific in origin, it is a proven formulation. It

contains some fairly expensive items, per unit weight, such as dried skim milk, brown sugar, and dried whole egg. However, if winning the purple ribbon is sufficient incentive, it is worth a bit more, perhaps, to pursue it to the very best of one's ability.

Since it is a rather complicated formula, the author has justified each item included in the formulation. The formulation (Table 16.15) should be pelleted into 0.25-inch (0.64-cm) pellets (smaller pellets will tend to be too hard and larger pellets will tend to be too crumbly, and lots of fine particles will accumulate in the feed trough). The diet should be essentially self-fed, which means it should be accessible at all times. To accomplish this, it would be best to use quantities which would not leave a great deal of feed remaining at the end of 24 h. This ensures that the feed is fresh. (There is something about fresh feed which is critical.) Thus, if the animal is given a new supply of feed once per day—or even once every 2 days—one can scoop out the leftover feed and give it to cattle not intended for show. Practice and observation will provide the expertise necessary to weigh out with a small amount what the show animal will consume, from day to day.

To the seasoned cattle feeder, the show formula looks very complicated—and it is. Furthermore, one might assume it is no better than a standard diet used in

TABLE 16.15

Complete Pelleted Formulation for Show Cattle (Growing and Finishing)[a]

Ingredient	1 ton mix (lb)	1 metric ton mix (kg)
Ground shelled corn (energy)	620	310
Ground corn cobs (roughage)	360	180
Ground barley (alternate energy)	400	200
Ground oats (roughage, palatability)	100	50
Cane molasses (aroma, palatability)	100	50
Dehydrated alfalfa meal (growth factors)	60	30
Soybean meal (high quality protein)	70	35
Linseed meal (protein, hair coat effect)	120	60
Dried whole egg (protein, hair coat)	20	10
Ground beet pulp (palatability)	100	50
Brown sugar (palatability)	16	8
Dicalcium phosphate (calcium, phosphorus)	10	5
Trace mineralized salt (salt, trace minerals)	4	2
Vitamin A	4 million IU	4.4 million IU
Vitamin D	200,000 IU	220,000 IU
Vitamin B complex	Add	Add

[a]Adding 2 g riboflavin, 10 g calcium pantothenate, 20 g niacin, 10 mg vitamin B_{12}.

the feedlot. However, one will never be sure until after giving the complicated show diet a try. The young showperson who does not have the experience is more apt to utilize a complex formulation than is a seasoned cattle feeder.

V. FATTENING BULLS FOR BEEF

Fattening of bulls for beef production is not as common in either the United States or Great Britain as it is in Continental Europe. Undoubtedly precedent and prejudice enter into the practice of castrating male calves intended for the feedlot in the United States and Great Britain.

Some of the reasons proposed for castrating bulls used to slaughter include (1) more management problems, (2) tougher meat, and (3) not enough fat covering on bull carcasses to prevent deterioration or spoilage of carcasses during the aging process. Admittedly, bulls older than 18 months are difficult to handle—and even potentially dangerous. Formerly, beef production practices resulted in slaughter of cattle 2 and 3 years of age, whereas today most young beef are slaughtered under 2 years of age. Bulls older than 18 months will have achieved sufficient masculinity that the meat will be tough. Finally, before rapid transit and well-refrigerated trucks and trains, fat on the outside of the carcass was perhaps more important in maintaining wholesome quality than it is today.

Today we are more knowledgeable in the production of youthful finished bull beef prior to the age of 18 months; the meat is tender, and well-refrigerated vehicles move such beef to its destination rapidly. Young bull beef cannot be graded as regular beef but must be called "bullock," which may carry a stigma for the potential buyer. Thus, young, high-quality bull beef still has not been accepted very well in the United States.

Continental Europeans, on the other hand, express a distinct preference for the less wasteful cuts of bull beef. Undisputed research has shown that bulls consistently gain more rapidly, require less feed per unit of beef produced, and produce leaner (less fat) carcasses than their castrate brothers. In addition, taste panel experts are not able to detect any difference in the meat from steers and from bulls.

A. Comparison of Bulls and Steers

Considerable research has been conducted to determine the nutrient requirements of high quality bulls. A comparison of the performance of bulls and steers under university conditions is of interest. Bulls and steers from the same herd—and thus the same genetic background—were compared in a 5-year study at Purdue University (Martin, 1974). The following are some conclusions derived from that research:

1. Bulls gained 13% faster than steers (2.27 versus 2.01 lb/day; 1.03 vs 0.91 kg), which resulted in an average 78 lb (35 kg) extra saleable animal at 18 months of age (Table 16.16).

2. Bull carcasses contained less fat. Actual chemical analyses of the 9–10–11 rib cut from bulls contained 22% more lean meat than the comparable cut from a steer carcass.

3. Bull carcasses were less marbled and graded lower (on a steer basis) than steer carcasses. Bull carcasses averaged high Select with "small to modest amount of marbling"; steer carcasses ranged between low and average Choice with "modest to moderate amount of marbling."

TABLE 16.16

Bull versus Steer Performance and Carcass Value (5-Year Study)[a]

Trait	Bulls lb	Bulls kg	Steers lb	Steers kg	Bulls compared to steers (%)
Performance adjusted to 441 lb (200 kg) weaning weight and 231 days weaning age					
Daily gain, postweaning					
First 28 days	2.54	1.15	1.94	0.88	+31
First 84 days	2.47	1.12	1.90	0.86	+30
First 140 days	2.32	1.05	1.88	0.85	+23
First 168 days	2.28	1.04	1.93	0.88	+18
300 days projected	2.03	0.92	1.76	0.80	+15
Slaughter weight	996	452	927	421	+7
Dressing percentage	62.7		62.1		
Carcass characteristics adjusted to 600 lb (272 kg) carcass weight					
Weight of cuts					
Chuck	96.8	44	82.8	37.6	+17
Rib	30.6	13.9	30.6	13.9	
Round	65.7	29.9	63.1	28.7	
Loin	46.8	21.3	47.6	21.6	
Primal cuts	233	106	225	102	
Kidney fat	9.1	4.1	11.5	5.2	
Carcass grade:	High Select		Low Choice		
Marbling score:	3.5 (modest)		4.5 (moderate)		
9–10–11 rib characteristics adjusted to 11.3 lb (5.1 kg) weight					
Lean content	6.2	2.8	5.1	2.3	
Fat content	3.0	1.4	4.4	2	
Bone content	2.0	0.9	1.7	0.8	

[a]Martin *et al.* (1966).

4. Palatability comparisons of loin steaks from bulls and steers showed little difference. Of six mechanical and panel measures of tenderness, four showed no difference and two slightly favored steer steaks.

5. Considering the four factors above, bull beef produced approximately 30% more edible product per animal than steers, and the product produced by bulls was slightly less marbled and only slightly inferior in palatability and tenderness to that produced by steers.

B. Effectiveness of Diethylstilbestrol for Bulls

Although diethylstilbestrol (DES) is not legal in beef production, results of a 2-year study are of interest; one might speculate that the use of a female hormone in bulls might suppress some of the effect of the bull hormone, testosterone. In this study, conducted at Purdue University, young bulls were implanted with DES at levels of either 36 or 72 mg. There was an immediate growth response of 0.2 lb (91 g) daily gain increase for the first 84 days which then rapidly disappeared. The net effect over 154 days was an average of 8 lb (3.6 kg) extra weight per implanted bull (0.05 lb/ day, or 23 g) over nonimplanted bulls. Subsequent research showed a greatly elevated serum testosterone level for implanted bulls, suggesting a counteracting adaptation effect by the testes of the implanted bulls.

C. Energy Levels

Three levels of energy for finishing bulls were compared in a 5-year study (Martin, 1974). The high-energy diet consisted of limited corn silage (15–20 lb/day, or 6.8–9 kg), a full feed of shelled corn (2% of body weight/day), plus a balancing protein supplement; medium-energy diet of corn was limited to 1% of body weight/day plus supplement and a full-feed of corn silage; low energy diet consisted of corn at a level of 0.5% body weight plus supplement and a full-feed of corn silage (Table 16.17). On the three energy levels compared, there were slight nonsignificant increases in daily gain (2.52 vs 2.63 vs 2.69 lb/day; 1.14 vs 1.20 vs 1.22 kg/day), for the low, medium, and high levels of energy. Based upon the energy comparisons, it would seem reasonable to feed a diet of 1% body weight as corn plus a full feed of corn silage and balancing supplement.

D. Levels of Protein for Young Finishing Bulls

A 2-year study was conducted to compare 14, 12, and 10% of protein in the diet of finishing bulls. The results are shown by 28-day periods in Table 16.18. High protein levels promoted most rapid growth in newly weaned bull calves starting at a weight of 480 lb (218 kg). These results have been duplicated in several years of subsequent research.

TABLE 16.17

Effects of Energy Level on Performance and Carcass Characteristics of Finishing Bulls[a]

	Dietary energy level					
	High		Medium		Low	
	lb	kg	lb	kg	lb	kg
Diet						
Corn silage	15–20	7–9		Full feed		Full feed
Corn (% body weight)	2%			1%		0.5%
32% protein suppl.	2	0.9	2	0.9	2	0.9
Daily gain	2.69	1.22	2.63	1.20	2.52	1.14
Feed per unit of gain	6.72		6.55		6.16	
Carcass characteristics						
Fat cover	0.45 in.	1.1 cm	0.37 in.	0.9 cm	0.33 in.	0.8 cm
Marbling score[b]		4.9		4.3		4.0
Carcass grade[c]		12.6		11.5		9.6

[a]Martin (1974).
[b]Slight = 4, small = 5.
[c]Choice = 12; High Select = 11; Average Select = 10.

E. Some Generalizations on Bull Feeding for Beef Production

1. Feed bulls for rapid gains to reach finish condition by 17–18 months of age. This ensures that the carcass will be most desirable and decreases potential management problems associated with more mature bull feeding.

TABLE 16.18

Protein Level Effect on Gains of Weanling Bulls[a]

	Dietary protein levels (%)					
	14		12		10	
Time period	lb	kg	lb	kg	lb	kg
			Daily weight gain			
First 28 days	3.01	1.37	2.65	1.20	2.44	1.11
Second 28 days	2.64	1.20	2.94	1.34	2.58	1.17
Third 28 days	2.55	1.16	2.56	1.16	2.39	1.09
Fourth 28 days	2.33	1.06	2.23	1.01	2.51	1.14
Fifth 28 days	2.23	1.01	2.39	1.09	2.38	1.08
Sixth 28 days	2.01	0.91	2.21	1.00	2.17	0.98
168-day total	2.46	1.12	2.49	1.13	2.41	1.10

[a]Martin (1974).

2. Do not shuffle and sort bulls among pens after they are 9 months of age. Start a group and leave them intact all the way to market. The reestablishment of the "peck order" among older bulls is stressful and can be destructive to equipment.

3. Pens for feeding bulls need to be sturdier than those for steers and heifers.

4. Young bulls can be fed much like heifers and steers. Be sure to use adequate levels of protein since bulls will lay down more muscle (proteinaceous) than steers or heifers; from weaning to 750 lb (341 kg) feed at least 12% protein; from 750 lb to slaughter, the diet should contain 10% protein.

VI. COMPARATIVE PERFORMANCE OF BULLS, STEERS, AND HEIFERS FOR BEEF

Three experiments were conducted by the University of Missouri (Hedrick *et al.*, 1969) to compare the feedlot performance and qualitative and quantitative carcass characteristics of half-sib Hereford bulls, steers, and heifers. In each of the three experiments, the progenies of three or four sire groups were represented

TABLE 16.19

Carcass Characteristics of Bulls, Steers, and Heifers[a]

	Bulls		Steers		Heifers	
Kill date:	Early	Late	Early	Late	Early	Late
Total gain						
lb	495	604	435	515	430	524
kg	225	274	198	234	195	238
Slaughter weight						
lb	1093	1257	937	1080	897	1018
kg	497	571	426	491	407	463
Carcass weight						
lb	595	654	579	642	601	659
kg	270	297	263	292	273	300
Age at slaughter, days	595	654	579	642	601	650
Carcass quality grade (No.)[b]	7.3	7.8	8.2	10.3	10.3	11.2
Total retail cuts (%)	70.4	65.3	64.6	59.4	61.2	60.0
Fat trim (%)	15.9	22.1	21.2	27.7	26.4	28.9
Bone (%)	13.4	12.3	13.6	12.8	12.3	11.5
Rib eye fat content (%)	4.3	5.8	6.3	10.8	8.6	10.1
Warner-Bratzler score[c]	17.9	17.9	15.5	15.0	16.2	17.4

[a]Hedrick (1978).
[b]Select = 7; Choice = 11.
[c]Warner–Bratzler score of pounds per 1-inch score.

evenly within sex group. After weaning, the calves were grazed up to 3 months and then placed in the feedlot. Within each sex, half the animals were killed at an "early kill" whereas the other half within each group was held for a "late kill" in order to bring out possible carcass differences within sex due to weight at time of slaughter. In all situations, the cattle were fed high-concentrate finishing diets for a major portion of the time; within each experiment, bulls, steers, and heifers were fed the same diet.

Bulls proved to be superior ($p < 0.05$) to steers and heifers in liveweight gain and feed conversion with steers and heifers showing comparable performance.

Total weight and percentage retail cuts of the carcass consistently were greater ($p < 0.05$) for bulls than for steers and heifers, and in several instances, they were superior for steers over heifers (Table 16.19). In all experiments, the percentage of ether extract (fat) in the longissimus muscle (rib eye) was less and carcass grade lower for bulls than for steers or heifers. Total amount of "throwaway" (trimmable) fat and intramuscular fat of all three sex groups increased as length of time on feed extended.

Warner–Bratzler shear values and sensory panel scores indicated that steaks from bulls less than 16 months of age were comparable in tenderness to steaks from steers and heifers of similar age. However, steaks from more mature bulls were less tender. Flavor and juiciness of steaks were not affected significantly by sex condition.

VII. FEEDING HOLSTEIN STEERS

Several decades ago it was not uncommon to kill male Holstein calves not intended for herd sire replacements shortly after such calves were born. Now, of course, the feeding of Holstein males to weights of 1000, 1200, 1500 lb (454, 545, 682 kg)—or even heavier—is most common. In addition, a large number of male Holsteins are started at 2 to 3 days of age on milk replacer formula for the production of white-meated veal.

The advantages of Holstein feeding include (1) extremely rapid gains of 4 lb/day (1.8 kg) or more, (2) more rapid turnover, and (3) usually a positive margin in selling price over purchase price, which is seldom ever achieved in feeding the so-called beef breeds. One of the obvious disadvantages is that since Holstein steers are a by-product of the milk-producing industry, there is not much chance of an increase in numbers of them available for purchase. In other words, the supply of Holstein steers tends to be relatively constant from one year to the next except that the number of dairy cows in this country has gradually declined (Fig. 16.6).

The University of Minnesota (Miller *et al.*, 1977) reported research on comparative methods of handling Holstein steers from 1 week of age until they are

Fig. 16.6 Holstein steer feeding has developed into big business in the United States. (Photo courtesy of BEEF Magazine.)

marketed as finished steers at approximately 1050–1100 lb (477–500 kg). In the Minnesota research, Holstein bull calves were purchased from dairymen at approximately 1 week of age. Such calves were placed in individual stalls with raised floors and were fed milk replacer for the first 28 days. At the time the calves were 45 days of age, they were taken from their crates and moved to a confined pole building where they were fed in groups of four to six calves until the pen of cattle was marketed.

The Minnesota researchers divided the test into several periods for examining various dietary regimens. These various stages of feeding are described. The first stage of the comparison was started after the calves had been on milk replacer for 10 days (they were about 17 days of age) and continued for the next 5 months (141–146 days). In other words, this program overlapped the milk replacer program from the 10th day on feed through the 28th day and henceforth constituted the only diet offered the calves until they weighed about 300 lb (136 kg), or until the calves had been on the test about 5 months. In this phase, the absence of hay or the presence of 15 or 30% hay was the basis of comparison (Table 16.20). These data show that the inclusion of about 15% of high-quality hay is desirable for starting young Holsteins. Later data will show that the calves fed 30% of hay responded somewhat better in subsequent performance. Nevertheless, it seems the inclusion of 15 to 30% high-quality hay in the diet is favorable from about 10 days of age to around 5 months of age.

TABLE 16.20

Holstein Calf Performance during the Period from 1 Week of Age to Approximately 300 lb (136 kg), 141 to 146 Days[a]

	Level of hay in the diet		
	0	15	30
Diet formulation (%)			
Rolled shelled corn	79.9	67.21	54.76
Soybean meal	17.6	15.5	13.27
Ground alfalfa hay	0	15.0	30.0
Dicalcium phosphate	1.45	1.63	1.62
Ground limestone	1.05	0.66	0.40
Vitamins A and D	Added	Added	Added
Performance			
Number of steers	67	71	73
Initial weight			
lb	94	94	97
kg	43	43	44
Final weight			
lb	313	323	323
kg	142	147	147
Days fed	146	141	144
Daily gain			
lb	1.49	1.62	1.56
kg	0.67	0.74	0.71
Daily feed dry matter			
lb	4.19	5.31	5.42
kg	1.90	2.37	2.46
Feed dry matter per unit gain	2.82	3.27	3.49

[a]Miller *et al.* (1977).
[b]Does not include 20 lb (9.1 kg) dry milk replacer per calf.

A feeder might possibly prefer to buy Holstein males (castrate) at 5 or 6 months of age. Thus, the Minnesota researchers compared feeding methods for Holstein calves starting at 5 months of age and weighing around 300 lb (136 kg), and extending until the steers were approaching 600 lb (272 kg) live weight (Table 16.21). In this research, a high-concentrate diet was compared with a predominantly corn silage diet.

From 300 lb (136 kg) to 600 lb (273 kg) (Table 16.21), Holstein steers fed the all-concentrate diet gained faster ($p < 0.01$) than those fed the high corn silage diet.

Many Holstein steer feeders prefer not to purchase steers until they weigh 600 lb (273 kg) or more and then start the finishing program. Minnesota researchers

TABLE 16.21

Comparative Gains of Holstein Steers on High-Concentrate and High-Silage Diets between 300 and 600 lb (136 and 273 kg)[a]

	All concentrate	High-silage
Number of steers	100	111
Initial weight		
lb	317	321
kg	144	146
Final weight		
lb	592	593
kg	269	270
Daily gain		
lb	2.42	2.12
kg	1.10	0.96
Daily feed dry matter		
Supplement		
lb	0.89	0.89
kg	0.40	0.40
Corn grain		
lb	10.1	2.5
kg	4.6	1.1
Corn silage		
lb	—	8.2
kg	—	3.7
Total		
lb	16.39	18.69
kg	7.45	8.50
Feed dry matter per unit gain	6.0	6.9

[a]Miller *et al.* (1977).

compared feeding programs for this size steer (Table 16.22). Certainly, in the finishing stage (600 to 1000 lb, or 273 to 454 kg), the Holstein steer is adapted to using at least 5 lb (2.2 kg) of corn silage dry matter (about 15 lb, or 6.8 kg, wet corn silage) per day. Dry matter conversion figures favor the all-concentrate program, but the lower cost of corn silage might tip the economical balance either way. However, Holstein steers tend to have large rumens and the consumption of an all-concentrate diet would not cause the ruminal distention (potbelly effect) caused by the silage diet.

In conclusion, for the young Holstein steer, a level of 15% of hay is effective between 1 week of age and 300 lb (136 kg) live weight; the all-concentrate diet is preferred for the gains between 600 lb (273 kg) and market finish.

TABLE 16.22

Finishing 600-lb Holstein Steers (273 kg) to Market on High Concentrates or Medium Silage Diets[a]

	All concentrate	Medium silage
Number of steers	107	104
Initial weight		
lb	592	594
kg	269	270
Final weight		
lb	1012	1002
kg	460	455
Daily gain		
lb	2.73	2.71
kg	1.24	1.23
Daily feed dry matter		
Supplement		
lb	0.89	0.89
kg	0.40	0.40
Corn grain		
lb	15.5	12.7
kg	7.0	5.8
Corn silage		
lb	—	5.1
kg	—	2.3
Total		
lb	16.39	18.69
kg	7.45	8.50

[a]Miller *et al.* (1977).

VIII. CULL COWS FOR SLAUGHTER

There is a market for almost any type of healthy beef animal. The cull brood cow which has completed her usefulness as a mother is no exception. However, the brood cow herdsman is apt to send such cattle to the auction barn or to the stockyards for sale. Conceivably the cow–calf herdsman might consider adding some finishing feed to cull cow diets before selling them, or cull cows could be assembled through auction rings and taken back to the farm to be fed a high-energy diet for a short time and then sold back for slaughter. Cull cows, no matter what their condition—and as long as they are healthy—make a lot of beef, including roasts and a few steaks, and also hamburger. Furthermore, cull cows are a prime source of filet mignon.

University of Missouri researchers (Murrow *et al.*, 1978) conducted research with cull Hereford beef cows, ranging in age from 6 to 11 years of age, which had been culled from the university beef herd. One group was slaughtered immediately to get estimates of carcass characteristics, while the other two of the three groups were fed on a heavy silage diet (60 lb or 27 kg/head/day) for either 28 or 42 days, and then slaughtered. The cows had excellent gains but those fed only 28 days gained over 3 lb/day (1.36 kg) (Table 16.23), whereas those fed 2 weeks longer tapered off considerably in their gains (1.89 lb, or 0.86 kg). It would appear that one would be justified in feeding cull cows a heavy feed of corn silage for up to 1 month, but after that time the profitability would drop off rapidly. However, this type of program does offer profit potential for a person who can manage such a program.

TABLE 16.23

Feeding Cull Cows Either 28 or 42 Days on a Heavy-Silage Diet[a]

	Length of time on silage (days)		
	0	28	42
Number of cows	18	18	18
Initial weight			
lb	976	1005	973
kg	444	457	442
Final weight			
lb	976	1090	1053
kg	444	495	479
Daily gain			
lb	—	3.05	1.89
kg	—	1.66	0.85
Feed per day			
lb	—	58	62
kg	—	26	28
Dry matter per unit gain		8.9	15.5
Final carcass value ($)	279.94	302.72	305.00
Amount of silage fed			
lb	—	1725	2604
kg	—	784	1184
Cost of silage ($)		17.25	26.04
Yardage at 15¢/day ($)		4.20	6.30
Silage plus yardage cost ($)		21.45	32.34
Cost per pound added weight (¢)		47.6	57.8

[a]Morrow *et al.* (1978).

IX. ESTRUS CONTROL IN HEIFERS: SPAYING VERSUS MGA

Occurrence of estrus in heifers is a recurring annoyance which probably contributes a great deal to the usually accepted lower rate of gain expected from heifers compared to that from steers. Typically, a heifer may stay in estrus 20 h and during that time she may be mounted a dozen or more times. Furthermore, she may eat very little during this period so that a combination of adverse conditions usually results in something less than optimal performance.

Veterinarians many years ago demonstrated that spaying, or surgical removal of the ovaries, prevented the occurrence of estrus in heifers. However, spaying has many obvious disadvantages. Often an animal will die because of surgical shock, internal hemorrhaging, or postsurgical infection. The surgical process is expensive as well as time-consuming because each animal must be restricted and operated on individually. More recently a spaying procedure utilizing a vaginal approach—as contrasted to entry from the flank—has been developed. The technique may not cause quite the stress to the animal of the former flank approach.

Another deterrent to spaying of heifers is the decreased performance which has been reported in the scientific literature (Table 16.24). In three trials reported, both growth rate and efficiency of feed conversion were depressed by spaying

TABLE 16.24

Effect of Spaying on Performance of Feedlot Heifers[a]

	Intact		Spayed	
	lb	kg	lb	kg
Average daily gain				
Trial 1	2.07	0.94	1.94	0.88
Trial 2	1.72	0.78	1.54	0.70
Trial 3	2.53	1.15	2.44	1.10
Average	2.11	0.93	1.96	0.89
Difference			−0.15	−0.04
Feed per unit of gain				
Trial 1	7.75		8.93	
Trial 2	11.12		11.88	
Trial 3	8.39		8.69	
Average	9.09		9.83	

[a]Trials 1 and 2, Purdue University; Trial 3, Upjohn Co. (Anonymous, 1978).

TABLE 16.25

Effect of MGA on the Feedlot Performance of Heifers[a]

	No drug	MGA
Daily gain		
lb	2.24	2.47
kg	1.02	1.12
Feed per unit gain	9.95	9.30

[a]Anonymous (1978), p. 26; 47 trials pooled.

heifers. Pooled results of the three spaying experiments show an average 7–8% decrease in rate of gain and efficiency of feed conversion by heifers which had been spayed.

During the development of melengesterol acetate (MGA), over 100 feeding trials were conducted to study the reaction of heifers. A number of such trials made direct comparison between MGA-treated versus no added drug for intact heifers. The average results of 47 such comparisons give MGA-treated heifers a 10% increase in rate of gain and a 6% improvement in efficiency of feed utilization (Table 16.25).

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17

Feedlot Disease[1]

Tilden Wayne Perry

A large-scale survey of nearly half a million feedlot cattle was conducted in Colorado (Jensen *et al.*, 1976) to determine causes of illness and death. The sickness rate of yearling cattle was found to be 5.1% with nearly one-fifth of these dying. Actually, about 1% of all yearling cattle in the feedlot died. Most of the cattle were 12 to 18 months of age, had originated outside Colorado, and included both steers and heifers.

The above survey showed respiratory diseases resulted in 75% of the sickness and 64% of the deaths. Pneumonia was the major disease and undoubtedly caused more economic loss than all other diseases combined (Table 17.1).

Nearly 72% of fatal cases of shipping fever pneumonia occurred during the first 45 days on feed, thus emphasizing the critical nature of getting new cattle well acclimated and started on feed. Pneumonia developed during all seasons but had a higher rate during fall and winter than during spring and summer. (See tabulation below.)

Days on feed	Incidence of fatal pneumonia (%)
1–45	72
46–90	14
91–141	9
142–up	5

Upon necropsy it was found that the tracheas and lungs contained both pathogenic and nonpathogenic organisms with the majority of bacteria isolated being from the *Pasteurella* group followed by the mycoplasmas. Infectious bovine diarrhea (red nose) virus was the most common viral agent identified.

IBR virus and pasteurellas have been recognized as probable causative agents for the shipping fever complex (Figs. 17.1 and 17.2).

[1]Much of the material presented herein was adapted from a paper presented by James Bailey (1977).

TABLE 17.1

Causes of Death in Colorado Feedlot Yearlings[a]

Disease	Percentage
Pneumonia	48
Brisket disease	6
Diphtheria	6
Intestinal infections	5
Riding injury	4
Bloat	3
Urinary calculi	2
Endocarditis	2
Ulcers	2
Bovine virus diarrhea	2
Pulmonary edema	1
Miscellaneous	17

[a]Jensen *et al.* (1976).

I. BULLING OR RIDING IN STEER FEEDLOTS

Bullers among steers is fairly common and represents a considerable economic loss to the cattle feeder. The main economic losses include physical injury, stress to both buller and rider, and the necessity of early isolation of the victims. Of nearly 2000 necropsies (Jensen *et al.*, 1976) performed in 1 year, about 4% (83) were diagnosed as riding injuries.

Fig. 17.1 New feeder cattle should be under the scrutiny of a veterinarian. (Photo courtesy of BEEF magazine.)

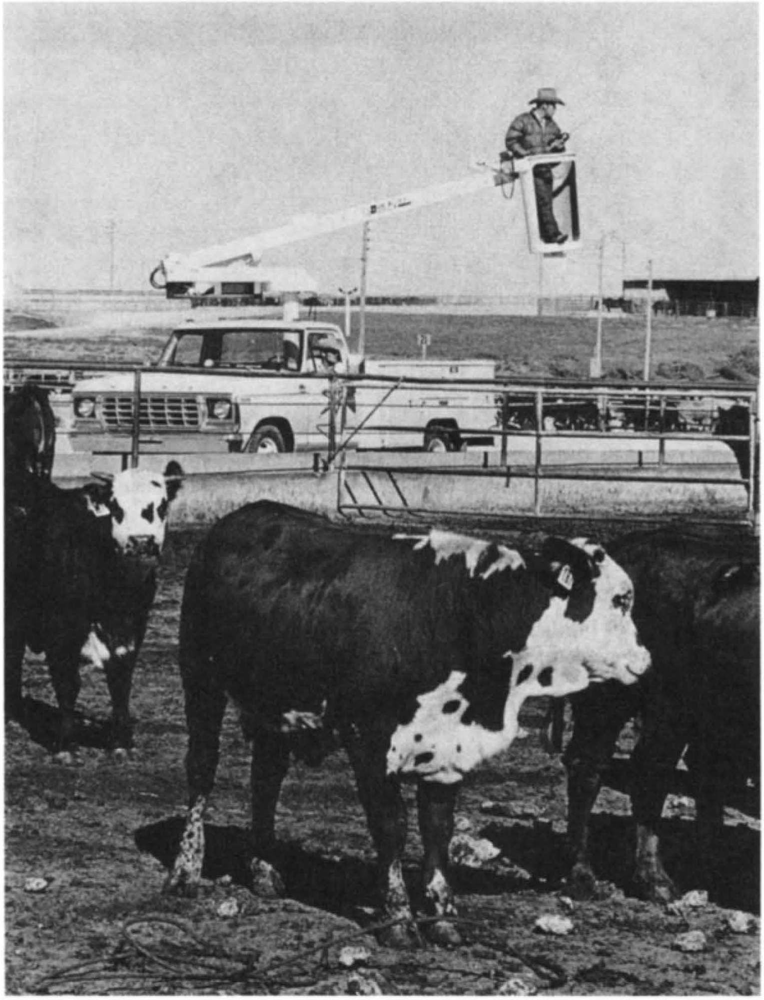

Fig. 17.2 A yard checker looks for sick cattle from the height advantage of a "cherry picker." (Photo courtesy of BEEF magazine.)

II. ACIDOSIS IN FEEDLOT CATTLE[2]

Acidosis in cattle is usually characterized by loss of appetite, diarrhea, mucus in feces, dehydration, incoordination, and often death. Physiological symptoms include increased rumen lactic acid levels, lowered rumen pH and blood pH,

[2]Much of the material on acidosis is adapted from published symposium proceedings on the subject (Brent, 1976; Elam, 1976; Huber, 1976; Slyter, 1976).

dehydration and hemoconcentration, rumen stasis, rumenitis, increased osmotic pressure within the rumen, destruction of gram-negative and proliferation of gram-positive bacteria, and reduction in rumen protozoa numbers.

It is generally accepted that acidosis is caused by excessive consumption of feeds rich in readily available carbohydrates. In fact, it has been demonstrated that manually engorging rumen-fistulated animals with grain or voluntary engorgement of starved animals with grain produces acidosis. Researchers have been able to produce acidosis in cattle by switching them from an all-hay diet to a 90% grain diet too rapidly. The author has witnessed the same situation when cattle on pasture were brought up on corn levels feed too rapidly.

A. Management Effect

Certain management factors appear to affect the onset of acidosis in cattle:

1. Starting Cattle on Feed

Often new cattle in the feedlot have never had more than token amounts of concentrates—other cattle may have much more. Therefore, background history of cattle may be helpful in determining the rate at which new cattle can be fed concentrates. Generally, however, it is best to utilize a high-roughage diet for new cattle and then work them up to a full feed of concentrates rather gradually.

2. Changing Diets

When raising the caloric or concentrate level of the diet, it is important to make such changes gradually. No increase in caloric content should be made when cattle are hungry. In fact, if feed is inaccessible, for example, due to a big snow or power and equipment failure, cattle should be fed a diet that is of lower energy content to appease the hunger. One can then proceed to the level of concentrate that was being fed prior to the interruption.

3. Feeding High-Energy Diets

It is difficult to feed a high-concentrate diet without experiencing some acidosis, founder, or bloat. In fact, Dr. Bart Cardon has suggested that he would like for about 1% of his finishing cattle to produce the gray off-color stool of acidotic cattle to indicate he is feeding just about the maximum level of concentrate possible. If some grain is replaced isocalorically with a combination of roughage plus fat there seems to be lowered acidosis incidence. Also, adding some variety to the grain portion by incorporating molasses-dried beet pulp in place of the corn, milo, or barley tends to reduce acidosis problems. Even though grain diets, in general, tend to predispose to acidosis, some grains are worse than others; wheat is generally considered to be the worst, followed by corn and milo, with barley being the least predisposing.

4. Weather and Season

The highest incidence of acidosis is observed during warmer seasons. The reason for the greater problem in summer is not known. Some keen observers have associated a higher incidence at times of weather change with the accompanying fluctuation in feed consumption.

5. Breed Differences

Brahman-bred cattle have been incriminated as the breed most proven to develop acidosis and founder. Florida researchers (Hentges, 1970) observed that following engorgement with a high-concentrate diet, blood cattle levels increased more rapidly in Brahmans than in Herefords or Angus cattle.

B. Physiological Effects of Acidosis

The lactic acid accumulation in the rumen and subsequent absorption initiate several physiological conditions which establish the acidosis syndrome.

1. Stasis of Rumen Motility

As the pH of the rumen declines to near 5, rumen contractions decrease and eventually cease altogether. The reason for this phenomenon is not understood.

2. Diarrhea and Dehydration

A reduction in total body water of 8% of the body weight has been reported in acidotic sheep (Huber, 1971). The reduction in body water was shared by plasma, interstitial, and intercellular fluid compartments. Rumen contents became excessively wet, indicating that at least part of the body water lost had entered the rumen. Fecal fluid loss via diarrhea is large and occurs when rumen motility is depressed. Algeo (1973) switched cattle abruptly from a high-roughage to a high-concentrate formulation. Sixteen of 75 cattle involved died, and the survivors had weight losses of 100 to 130 lb.

3. Systemic Acidosis

Acute acidosis in ruminants is the result of excessive consumption of fermentable carbohydrates, which causes a reduction in pH due to the production of large quantities of volatile and nonvolatile fatty acids. Furthermore, roughages have a much stronger buffering capability than concentrates. It appears to occur most readily when glucose accumulates in conjunction with a ruminal pH of 5 or less. At this lower pH, amylase of the ruminal ingesta is available, causing even more glucose to be liberated. During acidosis, the cellulose-digesting bacteria and protozoa are reduced greatly. It has been suggested that these organisms give stability to the rumen environment under normal conditions.

Unfortunately, animals which recover from acidosis may be plagued by other feedlot ailments. Laminitis often follows lactic acidosis, and even though there seems to be a close correlation, the biochemical relationship between the two conditions remains obscure. Laminitis is characterized by hyperemia, hemorrhage, and thrombosis with edema in surrounding tissues. There may also be severe vascular changes and extensive fibrous tissue formations in the cornium and, thus, the often elongated hoof. Because histamine is found in the rumen fluid of lactic acidotic animals, some would believe that histamine is the agent which triggers the laminitis syndrome.

Rumenitis and liver abscesses tend to closely follow acidosis conditions. With the advent of "no roughage" diets in the 1950s, damaged livers and rumens dramatically increased. Rumenitis and liver abscesses appear inseparable, since rumenitis (a consequence of acidosis) perhaps allows microorganisms to enter the portal circulation. Why acidosis predisposes rumenitis is not clear; many theories exist on the subject. However, since the liver represents as much as 5% of the carcass weight, damage to the liver can be extremely expensive. It has been suggested by the early work of the author and others that the feeding of low levels of antibiotics (70 mg per head daily) is of considerable benefit in decreasing the number of diseased livers in beef cattle.

Polioencephalomalacia (PEM) is a condition in feedlot cattle which also seems to have its origin in lactic acidosis. In the PEM condition, cattle become dull and blindness often ensues. Muscular tremors also occur as the disease progresses. Animals tend to press on fixed objects with their heads. After a few days they may die in a coma. PEM was attributed to a wide variety of causes but was finally shown to respond to large intravenous doses of thiamin (Davies *et al.*, 1965). Thiaminase, which destroys thiamin, was later identified in the rumen fluid of PEM cattle (Edwin *et al.*, 1968). Lactic acidosis appears to establish rumen conditions conducive to PEM development. As lactic acidosis develops, the rumen population changes from predominantly gram-negative species to predominantly gram-positive with an increase in bacilli. The pH drops to near ideal for thiaminase 1, and histamine levels increase.

III. SHIPPING FEVER

Shipping fever of cattle is a syndrome characterized by elevated body temperature, dypsnea, and pneumonia. It is a disease quite similar to the common flu in humans and is triggered by the stresses associated with handling and shipping cattle. Possibly because of the added stress of the weaning procedure, light calves appear to be more susceptible to shipping fever than do yearling feeder cattle. The shipping fever syndrome is probably the greatest loss to the cattle feeding industry of any common disease complex known, except where out-

TABLE 17.2

Summary of Research Utilizing AS-700 for the First 29 Days for New Feeder Calves

Location	Number of trials	Number of control cattle	Daily gain				Feed per lb gain		
			Average initial weight (lb)	Control (lb)	AS-700[a] (lb)	Improvement (%)	Control (lb)	AS-700 (lb)	Improvement (%)
Cyanamid									
Kansas	6	80	346	2.06	2.51	22	6.3	5.4	14
University									
Purdue	4	136	466	1.91	2.46	29	5.6	4.1	27
South Dakota	4	136	407	1.05	1.33	27	6.3	5.7	10
Texas	2	40	427	2.10	2.52	20	6.3	5.7	10
Iowa	2	76	666	1.24	1.38	11	13.6	11.2	17
Arizona	4	108	547	2.47	3.44	39	7.4	5.5	26
Kansas	5	136	372	2.05	2.26	10	6.8	5.9	14
Summary	27	712	437	1.89	2.33	23	7.9	6.3	19

[a]350 mg each of chlortetracycline and sulfamethazine per head daily.

breaks of hoof and mouth disease might occur. Some estimates for losses due to shipping fever in cattle run as high as 25 million dollars per year.

Many factors contribute to the avoidance of the shipping fever syndrome, including (1) good nutrition—especially a well-balanced protein supplement, adequate energy and minerals, and higher levels of vitamin A in the range of 50,000 IU per head daily; (2) proper care and management, including a comfortable, dry, draft-free, quiet place to recuperate; and (3) therapeutic levels of antibiotics and sulfa for the first 14 to 28 days on the farm. Naturally this program is not intended to preclude the usual therapy and prevention prescribed by the veterinarian, but rather is designed to complement the veterinarian's program.

Several universities and research stations have conducted extensive research and have proven the value of the high-level antibiotic–sulfa program treatment of new cattle. In four experiments at Purdue University, the feeding of a combination of 350 mg chlortetracycline (Aureomycin) and 350 mg sulfamethazine (the combination is known by the trade name AS-700) daily to newly arrived feeder cattle resulted in a 29% increase in daily gain and a 27% improvement in the efficiency of feed conversion over the 28-day adjustment period. Calves administered the AS-700 program in their feed weighed an average of 16 lb more than control calves not fed As-700 (Table 17.2).

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18

Economics of Cattle Feeding

Tilden Wayne Perry

I. THE CATTLE FUTURES MARKET[1]

There are three major categories of people who utilize the futures market: (a) speculator, (b) hedger, and (c) observer.

The speculator is the person who accepts the risk of a price change for a given commodity in the hope of making a profit. This individual would most likely ask the question, "How can I benefit from price fluctuations?" When buying or selling a contract, the trader is doing so because of the belief that price movements will be in a favorable direction, expecting contract prices to rise when buying and fall when selling.

The hedger uses the futures market to minimize the risk of a price change (Fig. 18.1), and thus shift the risk to someone else. In so doing, the hedger settles for a somewhat fixed price and thus responds to the question, "How can I protect myself from up-and-down price movements?" When buying or selling on contract it is more important to have similar price movements for the cash commodity and the futures contract than in the direction of such price changes.

The observer is the person who uses the futures market as a guideline of things to come and does not buy or sell futures contracts. Thus, the obvious question would be, "Is there any way I can use the futures market without active involvement?" Although the futures market would not be used as an exact price predictor, in this case it is useful as an indicator of the direction and magnitude of changes anticipated for the cattle industry (Fig. 18.2).

Why doesn't everyone employ the services of the futures market if this is a method of locking in at least minimal profit? Some typical answers to that question include: (a) "Its too complicated and I don't understand it," (b) "Someone I know was burned once and that's enough," (c) "I can't afford to use the futures market because it costs too much," or (d) "I don't want to shift the risk

[1]Much of the material utilized in this section is adapted by permission from a paper by Murra (1977), and updated by Erickson (1994).

Fig. 18.1 Selling of livestock on the futures may permit a certain built-in "safety" in the feeding business. (Photo courtesy of BEEF Magazine.)

Fig. 18.2 Feeder calves in an auction ring. (Photo courtesy of BEEF Magazine.)

because I'm a born gambler and I want a shot at greater profits even though I realize I might get some lumps, too."

A. An Example of Cattle Hedging

The following illustrates some of the actions which might be taken by a cattle feeder desiring to hedge cattle. The example, while illustrating the steps, is oversimplified but does provide a possible example. Also, the example is that of a perfect hedge, one where price movements of the cash and futures markets are the same; this is unlike in a real world situation. Also, in the example, only the fed cattle are hedged. Both grain and feeder cattle contracts can be used to lock-in input price.

Let's assume that on October 15 a cattle feeder evaluates the situation as follows:

1. 700-pound feeder steers sell for $83.00/ hundredweight.[2]
2. Add 550 pounds in 180 days @ 40¢ per pound gain.
3. Current price for April 15 contract is $74.50.
4. Price forecast for April ranges between $65 and $75.

On the basis of the above information the feeder decides to buy cattle, aim for the April market, and hedge the cattle. Scheme 18.1 illustrates the results of the enterprise, both if the prices go up and if they go down.

If one examines these examples "after fact," it is clear that hedging should be done only when prices decline—but who knows this in advance? However, the point of hedging is to shift risk. When feeder cattle are purchased, the cattle feeder either looks at the futures prices and decides to accept lock-in prices (futures prices today have anticipated futures prices) or not hedge and speculate that cash prices will move up favorably; to say that the cattle feeder should not have hedged since prices went up is nonsense. The cattle feeder who hedges does so with the best possible current information and possibly some nudging from the banker that has loaned the money to purchase the feeder cattle and feed.

B. What You Should Know as a Hedger

There are several items a hedger must know. These include, (a) production costs, (b)limits and requirements of the contracts, (c) basis, (d) a broker and

[2]Although the major portion of this text utilizes the Metric system of weights and measures, the English system utilizing pounds is employed since that is the manner in which cattle are bought and sold.

On Cash Market	*On Futures Market*
Oct. 15 Buy 700-lb Choice steers at \$83.00/cwt = \$581.00	Oct. 15 Sell April fed cattle futures contract at \$72.00/cwt
Oct. thru Apr. Add 550 lb at \$40.00/cwt = \$220.00. Total cost = \$801.00 divided by 1250 lb = \$64.08/cwt	Oct. thru Apr. Hold futures contract but continue to evaluate it to see if the hedge should be lifted

IF MARKET GOES UP

Apr. 15 Sell 1250-lb steers at \$74.50 = \$931.25 for a net above costs of \$10.42/cwt or \$130.25/head	Apr. 15 (or before) Buy April contract at \$72.00 = net loss of \$2.50/cwt or \$31.25/head

\$130.25 Gain on cash market
31.25 Loss on futures market
Net = \$ 99.00 ceiling on cash market

IF MARKET GOES DOWN

Sell 1250-lb steer at \$65.00 = \$812.50 = gain over cost of 92 cents/cwt or \$11.50/head	Apr. 15 (or before) Buy April contract at \$63.00 = net gain of \$2.02/cwt or \$25.20/head

\$11.50 Gain on cash market
25.20 Gain on futures market
Net = \$13.70/head due to futures market

Scheme 18.1

banker who understand hedging, (e) knowledge of factors affecting the market, and, (f) how the contract affects the hedger.

1. Costs

Knowledge of productive costs is always important, whether or not one uses the futures market. However, the importance is accentuated when hedging on the futures market because the final product price is established more firmly than when the product is not hedged. The example used earlier might best illustrate the point. There, the cattle feeder could buy 700-lb feeder cattle for \$83 per hundredweight; also the cattle feeder could utilize the futures market to lock in a price of \$74.50 for 1250-lb finished cattle. Should the cattle feeder feed the cattle and should they be hedged on the futures market? To answer these questions, the cattle feeder needs to know what the production costs will be in order to anticipate a profit. Naturally, the cattle feeder needs to know production costs whether hedging is practiced or not. Cattle feeders tend to be "eternal optimists," and enjoy listening to "high price" rumors. When a final price can be established prior to production, costs seem to be more important in decision-making evaluation.

2. Limits and Requirements

Futures contracts are written in a very specific language. Products involved are described carefully, with a discount schedule noted for delivery of products which do not meet specifications.

Often, the hedger's live cattle do not completely meet all the contract specifications. Thus, the price risk is not shifted entirely. How much is shifted depends on how closely the contract specifications are met, and, if different, how many differences there are in prices for the different categories.

3. Basis

The difference between cash price at any location and the futures price on any futures exchange is known as "basis." For example, if 1250-lb U.S. Choice Grade finished steers are worth \$75 in Sioux City, and a futures contract for finished steers on the Chicago Mercantile Exchange is selling for \$77, the basis is −\$2.00. For storable commodities, the futures price usually is higher than the current price; for cattle, this is not always the case. The basis depends on: (a) total supply and demand for the commodity, (b) supply and demand of substitute commodities, (c) geographical disparity in supply and demand, (d) transportation problems and prices, (e) storage availability (quality factors and condition capacities), and demand for futures contracts.

Since many of these factors vary by location, the basis must be computed for each location. Generally, the establishment of a firm localized net price for a fed steer is location A might be only \$71, while in location B it might be \$74, if the futures contract is priced at \$72.50. While this example is extreme, it is possible for one location to have a much different basis than another, even to the extent that one is positive and the other is negative.

As an example, computation of the basis for fed cattle in South Dakota has displayed a complex set of patterns. Generally, the establishment of a firm localized net price is not precise as is the case of grain. For example, in one given year, the Omaha cash–Chicago nearby futures contract ranged from +\$.50 in January to −\$3.58 in May. For the same months and locations in the succeeding year, the basis was +\$.54 and −\$1.34, respectively. Thus, the localized prices in the second year were closer to the Chicago futures price than was the case in the first year of the comparison. The variation in basis by the amounts noted results in a wider range of locked-in prices than if the basis were more stable. Even then, if the basis does not vary as much as the cash price, some risk can be shifted.

4. Broker and Banker

The hedger must know a good broker and a good banker (both knowledgeable and trustworthy). The broker facilitates buying and selling the contracts and also has current advice on "what to do." The banker supplies the credit, possibly for

both the cash commodity enterprise (feedlot) and the futures market costs (margins and brokerage fees).

5. Market Factors

Since both the cash price and the futures price are affected by market conditions, changes in these conditions and the effect of such conditions must be monitored. What may have been a good hedge this week might not be so good next week. Therefore, the feedlot manager must evaluate continually to see if a hedge is appropriate, if a hedge should be lifted, or if no market action is necessary. This evaluation is not something the feedlot manager should not be doing, rather, if the cattle are in the futures market a more frequent and structured evaluation may be required.

6. Effect on the Hedger

The hedger must analyze the impact of placing a hedge on both the operation and his personal well being. Questions include (a) "Do I like risks", (b) "Can I afford a big loss", (c) "Does the futures market make me more or less comfortable", (d) "Is credit easier or more difficult to obtain", and (e) "Do I feel safer"?

C. What to Watch For

The futures market is not necessarily all good or all bad. It can be a useful tool. Some of the major factors to keep in mind when deciding whether to use the futures market are discussed in this section.

1. It's Not What You Know, but Who

As noted earlier, the hedger must know a good broker and a good banker. A vast amount of knowledge about the futures market can be wasted if you do not have a good banker. This individual must both give sound advice and activate your requests as you want them activated. Also, if your banker does not understand or trust the futures market, its use may be discouraged. Sometimes this discouragement comes in the form of no credit!

2. There "Ain't No Such Thing as a Free Lunch"

What must be given up by the hedger to get price protection? After all, no one expects to get "somethin' for nothin'." First, there is a broker's fee. This fee is not large, and since a contract usually involves a minimum of 38 head of cattle, the cost can be $1.00—or more—per head. Secondly, margin money is required. Even when you sell a contract, you do not get money. Rather, you must put up earnest money. An interest charge should be made against earnest money. Usually, the margin required for a bona fide hedger is less than 10% of the contract value. For a 40,000-lb contract at $75 per hundredweight, a margin of $2000 to

$2500 might be required. Interest on $2500 at 8% would be $200 per year, or, if a contract were held 3 months, about $1.50 to $2.00 per head. Finally, the act of shifting price risk usually removes not only the potential for large losses due to price change, but also the potential for landslide profits due to price changes. The band of possible profits or losses is narrowed. To some, the loss of windfall profits may be the greatest cost of those mentioned. They enjoy the risk—and the potential gain or loss which goes along with it.

3. Nobody's Perfect

Even though the cash and futures prices generally move in the same direction, there are exceptions. In addition, the magnitude and/or timing of the move, even if in the same direction, usually are not the same. Thus, even though one can say that the futures market can be used to shift price risk, the above imperfections prevent this from being fully accomplished. However, if a portion of the risk is shifted, some of the original goal is attained.

As was noted earlier, the basis is a key to the use of the futures market. If the basis were always completely predictable, the perfect hedge could be more nearly attainable. Once again, however, if the basis varies less than the cash price, some risk can be shifted.

4. Once a Loser, Always a Loser

The futures market is not a gimmick which will automatically remove losses which go to the inefficient operator or which would occur in unprofitable market situations. In fact, the futures market, by locking-in a price for the final product, can just as easily lock-in a loss as it can a profit. At times, locking-in a loss may be advantageous, especially if it prevents a much larger loss. Merely going into the futures will not change an unprofitable operation into a profitable one. In fact, there may be instances when it is to an inefficient operator's advantage not to use the futures market. That is, if one does not lock-in a price in the futures market there is still the possibility that an extremely high price is extremely advantageous to the operator. Likewise, the extremely large losses resulting from a price slide downward are possible.

5. Do the Opposite

When using the futures market as a hedge, the principal rule is "do the opposite" in the futures market from what you do in the cash market. For example, when buying feeder cattle to fill your lots, sell a futures contract; when selling the cattle—or the month before—buy back the futures contract for the same product and month sold. If the opposite transaction is not followed, but rather the same position is taken in both markets, the result is a cash side which is not hedged plus ownership of a speculative contract on the futures side.

The opposite transactions provide the hedge because, generally, the cash and

futures markets move in the same direction. Losses in one market are offset by gains in the other, with the net result a shift in some of the price risk.

6. Apples Are Not Oranges

The quality specifications of a fad cattle contract, as noted earlier, are very specific. Specific weights, quality grades, yields, and sex are noted along with price discounts which are made if these specifications are not met. Many cattle feeders do not feed cattle which meet these rigid specifications, and economically, probably they shouldn't. However, this means that if the futures market is used, the hedge will be on something different than the cash commodity. The greater the difference there is, the poorer the hedge is in terms of shifting price risk, especially since all grades, weights, and sexes are not priced the same. The magnitude of these price differences is the key. It may not be as bad as comparing apples and oranges, but certainly an 800-lb yield grade 4, U.S. Select grade heifer is not the same as a 1100-lb yield grade 2, U.S. Choice grade steer.

7. A Pinch of Salt

There is an old saying that a pinch of salt is good, but that a cupful is better. Many participants get burned in the futures market because they apply the above concept in their futures market activities. They believe that it makes good dollar sense to hedge all or most of their cattle; it makes more sense to hedge several times what they actually have. Remember the hedge is an attempt to shift price risk on your cash inventory. It is not possible to shift price risk on something you do not own or expect to own. Going into the futures market with a volume greater than that on the cash side means acceptance of price risk, i.e., a speculator. The speculator's goal is profit. The feedlot operator does not need or want cattle to do that. It is extremely important to recognize the difference.

D. Using the Futures Market

The futures market's active participants are the hedger and the speculator. If neither of these roles is feasible or acceptable, the cattle feeder can still use the futures market. Basically, there are two ways one can do this. (1) Use the futures market as a guide to what prices are expected to be, and (2) use the futures market as a barometer in measuring the trade's reaction to livestock marketing information as it develops.

The futures market is not designed to be a price predictor. But since there must be both a buyer and a seller of futures contracts, some people are, in effect, predicting a price increase (the buyers) and others are predicting a price decrease (the sellers). In net, the predictions balance out so that usually the direction, if not the magnitude, of the expected price changes can be predicted. Again, although not perfect, it may be better than what many cattle feeders currently are using.

The use of the futures market as a barometer also can be beneficial. Basically,the futures market reacts to changes in supply and demand conditions. Since traders often have many dollars at stake, they are very current on these conditions and, when conditions change, the traders react accordingly. Just how much reaction takes place (how much prices go up or down) may give an indication to the nontrader as to what will happen. Because the futures market may be more psychological than the cash market, the barometer is not always completely trustworthy. But again, it may be better than the barometer being used currently by any given cattle feeder.

E. Basic Specifications for Fed Cattle Contracts

1. Par Delivery Unit

A par delivery unit is 40,000 lb of USDA yield grade 1, 2, 3, or 4 Choice quality grade live steers, averaging between 1050 and 1200 lb with no individual steer weighing more than 100 lb above or below the average weight for the unit. Not more than four head of estimated yield grade 4 Choice steers shall be permitted in a par delivery unit. No individual animal weighing less than 950 lb nor more than 1300 lb shall be deliverable.

Par delivery units containing steers with an average weight between 1050 and 1125.5 lb shall have an estimated average hot yield of 62%. Par delivery units containing steers with an average weight between 1125.6 and 1200 lb shall have an estimated average hot yield of 63%.

All cattle contained in a delivery unit shall be healthy. Cattle which are unmerchantable, such as those that are crippled, sick, obviously damaged, or bruised, or which for any reason do not appear to be in satisfactory condition to withstand shipment by rail or truck, shall be excluded. No cattle showing a predominance of dairy breeding or showing a prominent hump on the forepart of the body shall be deliverable. Such determination shall be made by the grader and shall be binding on all parties.

2. Weight Deviation

Steers weighing from 100 to 200 lb over or under the average weight of the steers in the delivery unit shall be deliverable at an allowance of 3¢ per pound provided that no individual animal weighing less than 950 lb or more than 1300 lb shall be deliverable. For purposes of computing such allowance, the weight of the over- or underweight animals shall be considered the same as the average weight per head of the delivered unit.

Steers weighing more than 200 lb over or under the average weight of the load are not acceptable. The judgment of the grader as to the number of such overweight or underweight cattle in the delivery unit shall be so certified on the grading certificate.

3. Yield Deviations

Delivery units with an estimated average hot yield under par shall be acceptable with a discount of 0.5¢ per pound for each 0.5% or less by which the estimated yield is under par. Units with an estimated average hot yield of less than 60% shall not be deliverable.

4. Yield Grade Deviations

Estimated yield grade 4 Choice quality steers, up to and including four head, are not deliverable at par.

All Select quality grade, yield grade 4 are deliverable at 3¢ per pound allowance for yield grade plus quality allowance.

If 9 or more steers of yield grade 4 (Select and Choice quality grade) are contained in the delivery unit, all yield grade 4 cattle in excess of 8 up through a maximum of 18 head are deliverable at a 3¢ per pound allowance.

For purposes of computing such allowance, the weight of such yield grade 4 steers shall be considered as the average weight per head of the delivered unit.

Any delivery unit containing more than 18 head of cattle with an estimated yield grade of 4 shall not be deliverable; cattle with an estimated yield grade of 5 shall not be deliverable.

5. Quality Grade Deviations

Delivery units containing not more than 8 head of USDA Select grade steers may be substituted at 3¢ per pound allowance for each Select grade steer. For the purpose of computing such allowance, the weight of Select grade steers shall be considered the same as the average weight per head of the delivery unit.

6. Quantity Deviation

Variations in quantity of a delivery unit not in excess of 5% of 40,000 lb shall be permitted at the time of delivery, with appropriate adjustment to reflect delivered weight but with no penalty.

7. Delivery Points

A par delivery of live cattle shall be made from approved livestock yards in Omaha, Nebraska; Sioux City, Iowa; Dodge City, Kansas; Amarillo, Texas; and Greeley, Colorado.

II. CUSTOM FEEDYARDS—WHAT ARE THEY AND HOW DO THEY WORK?

A custom feedyard is one that feeds cattle for customers for a fee. It furnishes room and board for someone else's cattle, much like a motel. Thus, one can actually become a cattle feeder without doing a bit of the work. This method then

permits absentee ownership of cattle, sort of like a parent sending their children off to college for the university to oversee. Usually the large commercial feedlot is so efficient, and certain overhead fixed costs are spread over such larger numbers of cattle, that it possibly can feed a private individual's cattle much more economically.

Services provided by the custom feedlot are many. Cattle are fed twice or three times per day; the feed is processed; all cattle are inspected every day; sick cattle are removed to protected "hospital pens" for treatment; marketing is optional but usually the commercial feedlot operator has a better "feel" for the market; and the commercial feedlot operator can arrange for the financing.

The commercial feedlot operator renders a variety of services for which compensation must be provided. Normally, the owner of the cattle receives a billing at the end of each month, except that the last month's billing is deducted from the sale of the cattle. Thus, on a group of cattle on feed 150 days (5 months), the owner will have to provide cash for 4 month's feed with the 5th month's feed bill being deducted from the sale price. The owner of the feedlot is in the business of selling feed as well as selling "room rent." The feedlot owner will charge a markup on feed sold ranging from 10 to 15%. Thus, feed costing $90 per ton might be marked up to $100 or $105 per ton. In addition, there is a per head per day pen charge of about 15¢. A steer in the feedlot for 150 days (times 15¢ per day) would have a room rent bill of $22.50, to be added to the cost of the feed. Furthermore, there will be a processing charge for incoming cattle covering dehorning, branding, dipping, castrating, worming, vaccinating, pregnancy checking, and implanting with growth promotants. Naturally, this will vary depending on the services rendered, but may run as high as 8 to $10 per animal. Cattle which become ill during the feedlot period may be removed for personal attention, and only medicinals utilized will be billed to the owner. At the end, if the feedlot owner markets the cattle, a charge of from $2 to $3 per head may be charged to the owner of the cattle, just as a commission company would require.

Financing arrangements have become fairly uniform in the cattle industry. Lending institutions located in cattle feeding country are especially attuned to cattle feeding capital requirements and are in business to do just that. Naturally, there are no set standards as to how much they will lend, but it should not be difficult to obtain 100% of the cost of the cattle, or 75% of the combined cost of the cattle and feed. One approach to this is to require the cattle owner to put up 25–30% of the purchase cost of the cattle with the lending institution supplying the other part. Then, as the monthly feed bills and any bills for illness come due, the lending institution and the owner pay their proportionate part to the commercial feedlot owner. Of course the cattle will increase in size and in their feed consumption, and potential market value may change—up or down—each month. Unless potential market value fluctuates markedly, the lender and the owner will pay their proportionate monthly feed bills. However, if the potential

market is declining, the owner may have to pay a larger proportion of the feed bill, depending upon the nature of the lending agreement between the lending institution and the cattle owner. Lending institutions tend to feel more at ease when the cattle are hedged to assure a definite sale price. Furthermore, policies for lending may vary a great deal.

What is the minimum number of cattle a person should have in a commercial feedlot? Usually this amounts to owning one pen of cattle. The typical commercial feedlot pen will hold 100, but this figure will vary among commercial feeders. It is almost imperative that any one pen not contain a mixture of cattle from two different owners because of the complexity of record keeping, billing, and compensating. The exception to this is in the case of cattle feeding clubs in which several people invest smaller amounts of money in an investment fund, and the manager of the fund then approaches the commercial feedlot operator to feed one or multiple lots of cattle. The normal feeding period is from 120 to 200 days and is dependent upon initial weight, type of cattle, and type of diet fed.

What is a normal investment per head for commercially fed cattle? In other words, what would it cost for a person to place cattle in a commercial feedlot? The following tabulation presents a set of hypothetical figures which will change from day to day, but nevertheless may present a set of "ballpark" figures for comparative purposes.

	Cost per head ($)	100 head ($)	30% owner's money ($)	70% owner's money ($)
Cost of 700-lb. steer at 85¢/lb	595	59,500	17,850	41,650
Gain cost for 500 lb at 45¢/lb	225	22,500	6,750	15,750
Interest on 70% borrowed money at 8%				
a. Purchase price	18.88			
b. Monthly bill, prorated	3.90			
Total cost	843.78	84,378	25,313.40	59,064.60

At market time, then, the 1200-lb steer must net $70.32 per 100 pounds ($843.78 cost divided by 1200-lb finish weight) for the owner to "break even" on the investment. These figures are not indicative of any potential profit and loss opportunity, but merely represent a model to which any given set of figures may be applied.

Who utilizes the commercial feedlot? One is the nonfarm investor who wishes to invest in the cattle feeding business just like he would invest in the stock market, for example. The tax advantage, once so attractive on prepurchased feed, has lost much of its tax shelter advantage. This type of investor should look at cattle feeding primarily on a sound investment basis.

Second, the farmer who is a cattle feeder may wish to expand investment in cattle feeding but does not wish to expand current facilities. In other words, the

producer has faith in the cattle feeding business and wishes to invest more heavily than present facilities will accommodate. One benefit of this method is that the monthly feed bill from the commercial feedlot keeps the farmer from keeping the home feedlot cattle too long.

A third type of commercial feedlot customer is the rancher who wants to maintain ownership of the ranch-raised feeder calves—and perhaps even add to that number—by having the commercial feedlot owner feed them to market finish.

Finding the right commercial feedlot and bargaining for the proper contract takes time and effort. Although most commercial feedlots operate on essentially the same basic principles, there are at least as many specific contract types as there are different commercial feedlots. It is a good idea for the potential customer to obtain referrals and to study customer close-out statements. Since no two pens of cattle will perform alike, several close-outs should be perused, looking at the beginning weights, number of days in the feedlot, daily gain, daily feed, feed per pound of gain, and, finally, net payout.

III. PREDICTING PERFORMANCE AND FEED REQUIREMENTS

Normally a cattle feeder calculates rate of gain and efficiency of feed conversion based on sale weight minus purchase weight, divided by number of days in

TABLE 18.1

Ration Types Fed Finishing Steers in a Mathematical Model of Feedlot Performance[a]

	Ingredient (% dry matter basis)			Net energy (therms/100 lb)	
Diet No.	Corn silage	Cracked corn	Protein supplement[b]	Ne_m	Ne_p
1	90.4	0.0	9.6	71.8	45.8
2	80.4	9.7	9.9	74.9	48.0
3	70.4	19.4	10.2	78.1	50.1
4	60.4	29.1	10.5	81.3	52.3
5	50.4	38.8	10.8	84.4	54.3
6	40.3	48.6	11.1	87.6	56.6
7	30.2	58.4	11.4	90.8	58.8
8	20.2	68.1	11.7	93.9	63.1
9	10.0	77.9	12.0	97.1	63.1
10	0.0	87.6	12.4	98.4	65.3

[a]Brent *et al.* (1978).

[b]Varied composition of soybean meal, limestone, dicalcium phosphate, salt, trace minerals, and vitamins to assure adequate balance.

the lot (for daily gain) and total pounds of feed consumed (for feed efficiency). Naturally, this represents "payout" data on which the cattle feeder's profit is calculated. However, this does not permit the cattle feeder to make interim assessments of "how am I doing" midway, or whether "nearly finished" cattle should be kept for additional increments of time. Kansas State University researchers (Brent *et al.*, 1978) have prepared a mathematical model to compare rate of gain, daily feed intake, and efficiency of feed conversion on finishing steers starting at a weight of 650 lb and fed 1 of 10 diet types; the diet types range from all-corn silage to all concentrates (Table 18.1). The series of tables presented permits calculation of costs at any given time and calculation of the costs of additional increments of gain. The cost of each pound of gain is composed of direct feed costs plus fixed costs such as interest and yardage. Thus, if a steer were fed a longer period of time on a low-cost diet, total cost conceivably could

TABLE 18.2

Daily Dry Matter Intake (lb) Computed from a Steer Performance Model

Steer weight (lb)	Diet number[a]									
	1	2	3	4	5	6	7	8	9	10
650	15.6	16.3	17.2	18.4	19.3	20.0	19.6	18.8	17.4	14.5
675	15.9	16.3	17.5	18.5	19.3	19.9	19.6	18.9	17.4	14.6
700	16.0	16.5	17.3	18.3	19.3	19.9	19.6	18.9	17.3	14.6
725	16.0	16.6	17.5	18.4	19.4	19.8	19.5	18.8	17.5	14.4
750	16.1	16.8	17.3	18.4	19.3	19.7	19.5	18.8	17.4	14.4
775	16.4	16.7	17.6	18.2	19.2	19.9	19.7	19.1	17.4	14.4
800	16.5	16.8	17.3	18.3	19.0	19.7	19.5	19.0	17.4	14.4
825	16.7	16.9	17.5	18.5	19.1	19.8	19.4	18.9	17.3	14.8
850	16.9	17.0	17.6	18.6	19.0	19.7	19.6	18.8	17.2	14.8
875	16.9	17.0	17.4	18.3	19.1	19.5	19.5	19.0	17.4	14.8
900	16.9	17.2	17.7	18.5	19.3	19.7	19.6	18.8	17.6	14.7
925	17.4	17.3	17.7	18.6	19.1	19.7	19.7	18.7	17.7	14.7
950	17.4	17.4	17.7	18.5	19.0	19.8	19.8	18.9	17.9	14.9
975	17.5	17.3	17.8	18.6	19.0	19.7	19.6	19.0	18.0	15.1
1000	17.7	17.4	17.8	18.5	18.9	19.7	19.7	18.7	18.2	14.9
1025	18.0	17.6	17.8	18.4	19.1	19.4	19.5	18.8	18.0	15.0
1050	18.0	17.7	17.8	18.4	19.1	19.3	19.3	19.1	17.6	14.9
1075	18.0	17.8	18.0	18.4	19.0	19.3	19.4	19.0	17.4	14.9
1100	18.9	18.0	18.1	18.6	19.0	19.4	19.6	18.9	17.4	15.0
1125	18.8	17.7	18.1	18.5	19.0	19.4	19.5	19.0	17.6	15.3
1150	19.1	18.0	18.2	18.5	18.8	19.5	19.6	18.7	17.5	15.3
1175	19.0	18.1	18.4	18.7	18.9	19.2	19.4	18.8	17.5	15.2
1200	19.1	18.3	18.4	18.8	19.0	19.2	19.3	18.7	17.7	15.1

[a]See Table 18.1.

TABLE 18.3

Daily Weight Gain (lb) at Various Body Weights Computed from a Steer Performance Model

Steer weight (lb)	Diet number[a]									
	1	2	3	4	5	6	7	8	9	10
650	2.11	2.44	2.77	2.97	3.17	3.39	3.56	3.76	3.70	3.72
675	2.07	2.40	2.73	2.93	3.12	3.32	3.50	3.70	3.63	3.65
700	2.02	2.35	2.66	2.86	3.06	3.26	3.43	3.63	3.54	3.56
725	1.98	2.31	2.61	2.79	2.99	3.19	3.37	3.54	3.50	3.50
750	1.94	2.27	2.55	2.75	2.93	3.12	3.30	3.48	3.41	3.43
775	1.91	2.20	2.51	2.68	2.86	3.06	3.23	3.41	3.34	3.34
800	1.87	2.16	2.44	2.62	2.79	2.99	3.15	3.34	3.28	3.28
825	1.83	2.11	2.40	2.57	2.73	2.95	3.08	3.26	3.21	3.21
850	1.78	2.07	2.35	2.51	2.68	2.86	3.01	3.19	3.12	3.15
875	1.74	2.02	2.29	2.44	2.61	2.79	2.95	3.12	3.06	3.08
900	1.69	1.98	2.24	2.40	2.57	2.74	2.88	3.04	2.99	3.01
925	1.67	1.94	2.18	2.35	2.51	2.66	2.82	2.97	2.90	2.93
950	1.63	1.89	2.13	2.29	2.44	2.60	2.75	2.90	2.84	2.86
975	1.58	1.82	2.07	2.24	2.38	2.53	2.68	2.84	2.77	2.79
1000	1.54	1.78	2.02	2.18	2.31	2.46	2.62	2.75	2.71	2.71
1025	1.50	1.74	1.98	2.11	2.27	2.40	2.53	2.68	2.64	2.64
1050	1.45	1.69	1.91	2.07	2.20	2.33	2.44	2.62	2.55	2.57
1075	1.41	1.65	1.87	2.00	2.13	2.27	2.40	2.53	2.49	2.49
1100	1.39	1.61	1.83	1.96	2.07	2.20	2.33	2.46	2.42	2.42
1125	1.34	1.54	1.76	1.89	2.00	2.13	2.27	2.40	2.35	2.35
1150	1.30	1.50	1.72	1.83	1.94	2.07	2.20	2.31	2.27	2.29
1175	1.25	1.45	1.67	1.78	1.89	2.00	2.13	2.24	2.20	2.20
1200	1.21	1.41	1.63	1.74	1.83	1.94	2.05	2.18	2.13	2.13

[a]See Table 18.1.

be greater, because of fixed costs, than if it gained more rapidly on a more expensive diet. Let us follow the calculation for a typical diet (Table 18.1). Diet No. 6 contains (on a dry matter basis) 40.3% corn silage, 48.6% cracked shelled corn, and 11.1% protein supplement.

Ingredient	Dry matter level (%)	Dry matter content (%)	Proportions, on as is basis (%)
Corn silage	40.3	35	62.65
Cracked corn	48.6	87	30.40
Protein supplement	11.1	87	6.95
Total	100.0		100.00

TABLE 18.4

Feed Efficiency (Units Dry Feed per Unit of Body Weight Gain) Computed from a Steer Performance Model

Steer weight (lb)	Diet number									
	1	2	3	4	5	6	7	8	9	10
650	7.4	6.7	6.2	6.2	6.1	5.9	5.5	5.0	4.7	3.9
675	7.7	6.8	6.4	6.3	6.2	6.0	5.6	5.1	4.8	4.0
700	7.9	7.0	6.5	6.4	6.3	6.1	5.7	5.2	4.9	4.1
725	8.1	7.2	6.7	6.6	6.5	6.2	5.8	5.3	5.0	4.1
750	8.3	7.4	6.8	6.7	6.6	6.3	5.9	5.4	5.1	4.2
775	8.6	7.6	7.0	6.8	6.7	6.5	6.1	5.6	5.2	4.3
800	8.8	7.8	7.1	7.0	6.8	6.6	6.2	5.7	5.3	4.4
825	9.1	8.0	7.3	7.2	7.0	6.7	6.3	5.8	5.4	4.6
850	9.5	8.2	7.5	7.4	7.1	6.9	6.5	5.9	5.5	4.7
875	9.7	8.4	7.6	7.5	7.3	7.0	6.6	6.1	5.7	4.8
900	10.0	8.7	7.9	7.7	7.5	7.2	6.8	6.2	5.9	4.9
925	10.4	8.9	8.1	7.9	7.6	7.4	7.0	6.3	6.1	5.0
950	10.7	9.2	8.3	8.1	7.8	7.6	7.2	6.5	6.3	5.2
975	11.1	9.5	8.6	8.3	8.0	7.8	7.3	6.7	6.5	5.4
1000	11.6	9.8	8.8	8.5	8.2	8.0	7.5	6.8	6.7	5.5
1025	12.0	10.1	9.0	8.7	8.4	8.1	7.7	7.0	6.8	5.7
1050	12.4	10.5	9.3	8.9	8.7	8.3	7.9	7.3	6.9	5.8
1075	12.8	10.8	9.6	9.2	8.9	8.5	8.1	7.5	7.0	6.0
1100	13.6	11.2	9.9	9.5	9.2	8.8	8.4	7.7	7.2	6.2
1125	14.0	11.5	10.3	9.8	9.5	9.1	8.6	7.9	7.5	6.5
1150	14.7	12.0	10.6	10.1	9.7	9.4	8.9	8.1	7.7	6.7
1175	15.2	12.5	11.0	10.5	10.0	9.6	9.1	8.4	8.0	6.9
1200	15.8	13.0	11.3	10.8	10.4	9.9	9.4	8.6	8.3	7.1

If we assume corn silage to be worth $25.00 per ton and to contain 35% dry matter, the cost per pound of dry matter is 3.57¢; corn costing $2.92 per bushel (56 lb/bushel), containing 87% dry matter, will have a dry matter cost of 6¢/lb. Similarly, a protein–mineral–vitamin supplement costing $300.00 per ton and containing 87% drymatter has a dry matter cost of 17.24¢ per pound. Diet No. 6, then, costs 6.26¢ per pound of dry matter (4.40¢ per pound, as fed). Table 18.2 indicates that an 800-lb steer being fed diet No 6 (Table 18.1), 19.7 lb of dry matter, gains 2.99 lb per day (Table 18.3) and requires 6.6 lb of feed dry matter per pound of gain (Table 18.4). The above diet cost calculations indicate the cost of diet No. 6 dry matter is 6.26¢/lb. Thus, on diet No. 6, an 800-lb steer consuming 19.7 lb of dry matter, gaining 2.99 lb per day, and thus requiring 6.6 lb of feed per pound of gain, would have a feed cost per pound of gain of 41¢. Consider the feed cost per pound of gain for a 900-lb steer; from Table 18.4, one

can observe that feed required of Ration No. 6 per pound of gain for a 900-lb steer is 7.2 lb, for a feed cost of 45¢. An 1100-lb steer requires 8.8 lb of No. 6, for a feed cost of 55¢. Naturally, overhead costs have not been included, nor have any interest costs on the feed been included.

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19

Environmental and Housing Effects on Feedlot Cattle Performance[1]

Tilden Wayne Perry

Cattle feeding housing ranges all the way from no housing, no windbreak, and no paving underfoot to the most sophisticated enclosed environment complete with heat and humidity-sensitive fans. Naturally each additional dollar spent on equipment must be deducted from gross profit unless its use contributes a reduction in expenses. The purpose of this chapter is to summarize research data designed to sort out the pros and cons of various types of equipment which contribute to altering the environment of finishing beef cattle. Most of the data presented are based on research conducted in the North Central region of the United States, but undoubtedly these effects may be adjusted and applied to many other sections of the world where cattle may be fed.

I. HOUSING EFFECTS

A. Housing versus No Housing

A further breakdown is needed under this subheading, namely, the effects of winter housing and of summer housing. Iowa State University has conducted a number of trials to determine housing effect on winter performance. The reader should understand that Iowa winters can be extremely severe when temperature, humidity, and wind velocity all are taken into account. In yearling steer comparison, average daily gain was depressed from 9 to 18% and feed cost was increased from 7 to 21% for cattle which had no shelter (Self, 1964, 1965; Self and Hoffman, 1967). Michigan researchers (Greathouse and Henderson, 1968) compared calves wintered outside with no housing, windbreak, or bedding against calves wintered inside, bedded, and completely under roof. Daily winter gains for the outside group were depressed 14% and feed cost increased 23%. How-

[1]Much of the material used in this section is from a handout presented by Henderson and Geasler (1968).

ever, when bedding and housing costs were added to feed costs for the inside group, their total costs were greater.

The data presented in Table 19.1 are quite consistent, showing a uniform drop in daily gain of 12% and increase in feed cost of 14% for no shelter fed cattle.

In summer comparisons, eight studies are summarized (Table 19.2). Performance favoring shelter for summer-fed cattle was much less dramatic with an average of 5% increase in gain and 4% decrease in feed cost. It is doubtful that the advantage for summer shelter will pay for the cost of providing summer shelter.

B. Comparison of Type of Housing

A number of trials have been conducted to compare performance of cattle fed in 40% and 100% covered lots. Michigan researchers (Henderson and Newland, 1965, 1966a,b, 1967; Henderson *et al.*, 1965, 1967a,b) conducted three winter trials for this type comparison and reported no difference in gain (2.50 lb per day) or in feed required per pound of gain (7.36 lb). The same researchers found no difference in performance in summer trials for 40% and 100% shelter over cattle finishing feedlots. Ohio workers (Roller *et al.*, 1960) conducted five studies and reported the results by 56-day cold and warm periods. During the cold period, cattle under 40% shelter gained 4% slower (2.03 versus 2.11 lb per day) and had

TABLE 19.1

Summary of 13 Trials of No Shelter Effects on Winter Gain of Feeder Cattle

Station	Type cattle	Date	Decrease daily gain (%)	Increase in feed cost (%)
Iowa	Yearling	1962	18	21
Iowa	Yearling	1963	15	17
Iowa	Yearling	1965	15	15
Iowa	Yearling	1966	11	8
Iowa	Yearling	1967	13	14
Iowa	Yearling	1968	9	7
Ohio	Calf	1959	2[a]	8[a]
Michigan	Calf	1968	14	23
Michigan	Calf	1968	10	14
Kansas	Yearling	1961	22	28
South Dakota	Calf	1968	4[a]	4[a]
Connecticut	Calf	1963	7[a]	12[a]
Saskatchewan, Canada	Yearling	1958	15	14
Average of 13 trials			12	14

[a]No shelter groups had bedding in experiments indicated.

TABLE 19.2

Summary of Eight Trials of No Shelter Effects on Summer Gains of Feeder Cattle

Station	Type cattle	Date	Decrease in daily gain (%)	Increase in feed cost (%)
Iowa	Yearling	1962	6	4
Iowa	Yearling	1964	7	7
Iowa	Yearling	1965	7	5
Iowa	Yearling	1966	4	1
Iowa	Yearling	1967	3	3
Kansas	Yearling	1961	7	8
South Dakota	Yearling	1967	2[a]	5[a]
Ohio	Yearling	1964	7	−2
Average of 8 trials			5	4

[a]Bedding provided for no shelter group.

a 12% higher feed requirement per unit gain than cattle under 100% shelter. However, this reversed during the 56-day warm period with cattle under 100% shelter gaining 8% slower and requiring 3% more feed per unit of gain than cattle with only 40% shelter.

C. Feedlot Surfaces

Data on this subject are not too plentiful, but Iowa State University (Self, 1964, 1965) has reported three winter trials and three summer trials which are summarized in Table 19.3. Differences in performance due to feedlot surface type were negligible for both winter and summer comparisons. This seems to be the general rule reported by researchers who have investigated the subject. However, this author conducted research on the subject and although there was no difference between cattle on paved lots and unpaved lots during two very dry summer comparisons, there was a marked difference in performance during a very wet summer. In this research it seemed the cattle in the unpaved lot preferred not to wade through the mud to get to the feed bunks.

1. Slatted versus Bedded Floors

The Ohio Experiment Station (Klosterman *et al.*, 1964, 1965) results from a 2-year period were summarized and no difference in performance was obtained between cattle housed on steel slats and those on bedded concrete floors. The Ohio researchers assessed a bedding cost per cwt of gain of about 43¢ for the bedded cattle (95¢/100 kg gain). Michigan data (Henderson *et al.*, 1967b) con-

TABLE 19.3

Feedlot Surface Type Effect on Cattle Performance[a]

	Surface type		
	Concrete	Part concrete	Dirt
Winter research (three trials)			
Daily gain (99 to 151 days)			
lb	2.52	2.54	2.60
kg	1.14	1.15	1.18
Feed required/unit gain	11.3	11.3	11.0
Summer research (three trials)			
Daily gain (142 days)			
lb	2.72	2.69	2.70
kg	1.24	1.22	1.22
Feed requirement/unit gain	9.5	9.6	9.6

[a]Self (1964, 1965).

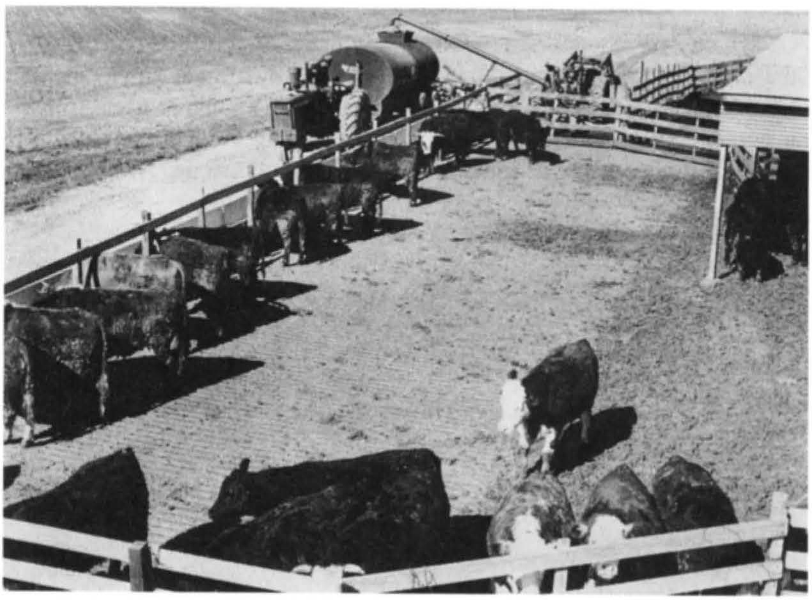

Fig. 19.1 Slatted feedlot floors outdoors decrease space and bedding requirements. (Photo by J. C. Allen and Son.)

Fig. 19.2 Finishing beef cattle on slats, under roof, require from 20 to 23 square feet of floor space per head. (Photo by J. C. Allen and Son.)

firmed Ohio data by which gains of steer calves (2.60 vs 2.67 lb/day, or 1.2 kg/day) and feed required per unit of gain (7.1 vs 6.6) were similar for those on slatted and those on bedded floors (Fig. 19.1 and 19.2).

2. Slatted versus Concrete Floors without Bedding

Michigan researchers conducted two winter trials to compare these conditions. Differences in performance were small in both trials, favoring the unbedded concrete floor group in the first trial and favoring the slatted floor group in the second trial, indicating that cattle should be expected to perform equally well on either type of floor.

II. ENVIRONMENTAL EFFECTS

A. Effect of Summer Shade

Summer temperature and summer humidity can be a stressful combination for feedlot cattle. Thus the value of shade has been researched by Kansas and Georgia research stations. Table 19.4 illustrates that shade may be beneficial under many summer conditions.

TABLE 19.4

Summer Shade Effect on Yearling Feedlot Cattle Performance (Kansas and Georgia)

	No shade	Shade
Kansas (three trials)[a]		
Daily gain		
lb	1.99	2.12[b]
kg	0.90	0.96[b]
Feed/unit gain	10.1	9.8
Georgia (four trials)[c]		
Daily gain		
lb	2.17	2.23
kg	0.99	1.01
Feed/unit gain	10.2	10.1

[a]From Boren *et al.* (1961).
[b]$p < 0.05$.
[c]From McCormick *et al.* (1963).

Research at the Imperial Valley Field Station, California (Ittner and Kelley, 1985; Ittner *et al.*, 1954), suggests that the primary function of shade is to reduce the heat intake of cattle subjected to the absorption of the radiant energy of the sun. They suggest shades should be 10–12 feet (3–3.6 m) above the ground, and should provide 60 square feet (5.6 square meters) of shade per head of cattle.

Temperatures at the Yuma, Arizona Station (Nelms and Roubicek, 1975) were even more severe than those in California and may remain in excess of 100°F (38°C) for one-third of the year. Gains made by cattle provided with shade at the Yuma Station were significantly higher than gains for those not provided with shade.

It has been suggested that when temperatures rise above 80°F (27°C) some sort of shade should be provided; this condition may exert more feedlot stress than temperatures below freezing.

B. Feedlot Lighting

Most large feedlots provide night lighting. The cost is probably justified because it seems to have a tranquilizing effect on the cattle. Kansas researchers (Boren *et al.*, 1965; Smith *et al.*, 1964) reported two trials designed to compare the performance of cattle which did or did not have night lighting. The lighting arrangement consisted of 25-watt incandescent lamps spaced 8 feet (2.4 m) apart, suspended under reflectors, 7 feet (2.1 m) above the feed bunk. A photoelectric cell turned the lights on at dusk and off at dawn. It was concluded that the

TABLE 19.5

Effect of Animal Density on Feedlot Performance of Beef Cattle[a]

	Area per animal							
Square feet:	20	25	30	35	40	45	50	55
Square meter:	1.9	2.3	2.8	3.2	3.7	4.2	4.6	5.1
February to June								
Initial weight								
lb		704		704		705		704
kg		320		320		320		320
Final weight								
lb		981		973		1003		981
kg		446		442		456		446
Daily gain								
lb		2.41		2.34		2.59		2.41
kg		1.10		1.06		1.18		1.10
January to July								
Initial weight								
lb	430	430	429	429				
kg	195	195	195	195				
Final weight								
lb	946	958	986	1000				
kg	430	435	448	454				
Daily gain								
lb	2.43	2.48	2.62	2.68				
kg	1.10	1.13	1.19	1.22				
April to August								
Initial weight								
lb	637	637	657	650				
kg	290	290	299	295				
Final weight								
lb	881	899	931	928				
kg	400	409	423	422				
Daily gain								
lb	1.81	1.94	2.02	2.06				
kg	0.82	0.88	0.92	0.94				

[a]Henderson and Newland (1966a); Henderson *et al.* (1967b).

presence of night light had no effect on feedlot cattle performance. However, the presence of night lighting might prevent cattle "spooking" and similar strange things.

C. Animal Density

Three trials at Michigan State University (Henderson and Newland, 1965, 1966a,b; Henderson *et al.*, 1965, 1967a,b) have compared a broad range of area

allotments of floor space for finishing both steers and heifers in bedded lots, completely under roof, but open to the south (Table 19.5). Following completion of the third trial, the Michigan researchers concluded that the area requirements of feedlot cattle are a function of body weight with minimum requirements being 2 square feet of bedded area under roof/100 lb body weight (0.4 m^2/100 kg) during winter months and increased to 3 square feet (0.6 m^2) during summer months.

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Appendices

Appendix I

Implants and Nonnutritive Additives for Beef Cattle[1]

Tilden Wayne Perry

Many of these products are under the control of the United States Food and Drug Administration; therefore, there is some risk in listing "currently legal" products in a text which may be in print a number of years before it is revised. One example of such is diethylstilbestrol which was legal at the time the first edition of this text went to press in 1980. Shortly after that time, diethylstilbestrol was withdrawn from the list of legal implants or feed additives. Another example which has worked somewhat in the opposite direction is bovine somatotropin (BST) which has been approved by the FDA for use in lactating dairy cows; conceivably this engineered growth hormone might become legal for use as either a growth promotant or as a stimulant for milk production in lactating beef cattle.

Most of the products for ruminants have been developed for feedlot or growing cattle. The Feed Additive Compendium, published by the Miller Publishing Company (Minneapolis, MN), provides information on all approved feed additives for all species; it lists manufacturers, recommended dosages and withdrawal times.

Implants

All available beef cattle implants are listed in Table AI. Hormones used in implants are (1) estrogens, either estradiol (the naturally occurring estrogen) or a

[1]The material in this section was adapted from material supplied by Allen Trenkle, Iowa State University, and Kern Hendrix, Purdue University.

nonsteroid estrogen-like compound (zeranol, progesterone), or (2) androgens, either testosterone (the naturally occurring hormone) or the synthetic androgen, trenbolone acetate (TBA). The greatest growth response occurs when estrogens are combined with steroids. Implants are either compressed tablets which dissolve over a period of 80 to 100 days after implantation under the skin of the animal, or the hormone is dissolved in a silicone rubber implant which slowly releases the hormone over a 200-day period once it has been implanted. All implants must be placed under the skin on the back side and middle one-third of the ear. The ears should be clean and dry when cattle are implanted. All needles should be kept clean and disinfectant should be used between animals; do not use alcohol as the disinfectant, since many of the hormones and/or carriers are soluble in alcohol. Briefly pinch the injection site with the thumb and index finger after withdrawing the implant needle.

The response to the implants containing estrogen is similar if the compressed pellets are reimplanted after the period of time recommended by the manufacturer. The original implant and reimplant both cause an increase in rate of gain of 9 to 12% and result in an improvement in efficiency of feed conversion of 8 to 10%. Feed intake usually is increased about 2% to 5%. An effective implant program results in increased nitrogen (protein) retention as well as increased retention of calcium and phosphorus, indicative of a true growth response. There is decreased retention of energy/energy consumed because there is less fat deposition and more lean in the gain when the cattle are implanted. Cattle respond to implants at all ages but the greatest response occurs in steers fed high-energy feedstuffs during the feedlot finishing period. The response before weaning is similar in bulls, steers, and heifers; after 7 to 9 months of age, steers respond more than heifers and heifers more than bulls. In fact, implantation of bulls will give little or no growth response, but there may be more fat deposited resulting in improved carcass grades for bulls which are slaughtered. Implanted bulls are less aggressive in the feedlot; bulls that will be used for breeding purposes should never be implanted. The reproductive performance of heifers implanted with estrogens as calves is not affected.

Once implanted, cattle need to be reimplanted every 80 to 100 days (or approximately 150 days with timed release implant) to maintain a positive response. The intended use of the cattle should determine the implant program. If calves are to be sold as feeder cattle after weaning or a growing period, implanting shortly after birth can be justified economically; they should be reimplanted at time of weaning if ownership is to be retained during the postweaning growing period. If ownership is to be retained after weaning and through finishing, all response to the implants can be obtained if the first implant is delayed until after weaning.

Cattle entering the feedlot should be implanted and reimplanted after 60 to 80 days if the feeding period is to be more than 120 days. It is important to know at the time of purchase of feeder cattle what the presale implant program has been,

if at all possible. Switching products at the time of reimplanting is practiced by some, but there is no conclusive evidence to support this practice. For reasons which cannot be predicted, some cattle show more response to reimplanting during the finishing period. Consequently, such cattle may often produce carcasses with less marbling and therefore lower grading.

Compared with testosterone propionate, TBA has 3 to 5 times the androgenic activity and 8 to 10 times the anabolic activity. Implanting TBA alone stimulates the growth of steers in the feedlot, although less than estradiol, but there is a greater response to TBA alone in heifers than in steers. Combining TBA with an estrogen increases gain and improves feed efficiency more than either one alone in both steers and heifers. There is no effect on dressing percentage. There is no indication of a major reduction in carcass quality as measured by backfat thickness, but marbling is frequently reduced and maturity of the skeleton may be increased, which impacts quality grades of the carcass. There is no evidence that color, tenderness, or palatability of the muscle is affected. The increased gain and improvement in feed efficiency from TBA when added with an estrogen averages 4 to 7% above estrogen alone, which would make such practice practical. TBA is best used as a terminal implant about 100 days pre-slaughter. Thus, the implant program for cattle destined to 120 to 140 days in the feedlot would be to use an estrogen implant at the time cattle are started on feed, followed by reimplanting with estrogen plus TBA 90 to 100 days before slaughter. Somewhat greater improvement in feedlot performance of steers and heifers is obtained by implanting with TBA and estrogen at the start of the finishing period and reimplanting with the combination midway through the finishing period for cattle to be fed more than 120 days, but there may be some decrease in quality grades of the carcasses. The effect of reduction in quality grade on economic returns depends on the discount of U.S. Select grading carcasses. There are times when such discount is enough to negate the positive physiological benefits of reimplanting TBA on the performance of the cattle. Heifers implanted with an estrogen plus TBA also show some response to the feeding of melengesterol acetate (MGA, a synthetic progesterone).

Some problems associated with the use of implants include (1) increase in the size of accessory sexual glands of males, especially in sheep, which may result in rectal prolapse and difficult urination; (2) loss of implants from infected implant sites—ears should be clean and dry when implanted; (3) increased incidence of "bullers" (from approximately 0.5% bullers in cattle not implanted to 0.5–2.5% in implanted cattle); (4) there is reduction in size of the testis in young bulls, but there is no permanent effect upon reproduction in females implanted as calves; (5)residues in the liver, kidney, and fat tissues if tissues are taken a few days after implantation. However, the U.S. Food and Drug Administration has approved the use of implants in feedlot cattle without requiring a withdrawal time before such cattle are slaughtered for human food.

Feed Additives

Melengesterol Acetate (MGA)

MGA is a synthetic progesterone; it has been approved at levels of 0.25 to 0.5 mg/head/day in the feed of finishing heifers. Its use causes increased gain of 6 to 8% and results in 5 to 7% improved efficiency of feed conversion. A 48-h withdrawal period prior to slaughter is required. MGA suppresses estrus also, but it blocks secretion of the luteinizing hormone (LH) from the anterior pituitary gland so that the follicles of the ovary do not ovulate. Continued secretion of the follicle-stimulating hormone (FSH) from the pituitary stimulates the secretion of estrogen from the ovarian follicles which acts like exogenous estrogen from implants.

Ionophores

Two ionophores have been approved for use in cattle; both are cleared for cattle kept in either drylot or on pasture. No withdrawal is required for either product.

a. Monensin (Rumensin) has been cleared for feeding at 5 to 30 g/ton of 90% dry matter feed. Common feedlot practice seems to be to include about 25 g/ton.

b. Lasalocid (Bovatec) has been cleared for feeding at 10 to 30 g/ton of 90% dry matter feed.

The use of ionophores causes an alteration in rumen fermentation pattern such that there is an increase in propionic acid production; this results in more efficient fermentation so that there is reduced hydrogen and carbon dioxide loss. A greater growth response to ionophores is obtained with cattle fed high-roughage rations than with those fed high-grain diets. Filling of the digestive tract limits feed intake of roughage, so feed intake is not reduced when an ionophore is fed. The increase in propionate and the associated improvement in feed efficiency results in some increase in gain. With high-roughage rations, gain is increased 5 to 8% and feed efficiency improved 10 to 15%; with high-grain rations, the use of ionophores tends to reduce feed intake. Bovatec may increase gain about 4% and improve feed conversion 8%. Combinations of an implant program and the feeding of an ionophore will increase gain and improve feed efficiency from 15 to 20%; the combination of MGA and Rumensin or Bovatec has been cleared for use in heifers.

Antibiotics

Antibiotics sometimes are fed continuously at low levels (75 mg per day) to control subclinical infections or to decrease the incidence of liver abscesses. The average performance response in feedlot cattle is 3 to 4% increase in gain and 2 to 3% reduction in feed required per unit of gain. There is no required withdrawal period from the feeding of this low level of antibiotic. Another use of antibiotics

is to feed much higher levels (350 mg and up to 1 g/ day) for the first 28 days after cattle arrive in the feedlot to help control the incidence of shipping fever in such stressed cattle. A 7-day withdrawal period is required with the feeding of therapeutic levels (350 mg/day) of antibiotics. The feeding of antibiotics is not approved for feeding to lactating dairy cattle.

Antibiotics used commonly for cattle feeding include tylosin, chlortetracycline, oxytetracycline, bacitracin, and penicillin.

TABLE AI

A Listing of Implants and Feed Additives for Beef Cattle Which Act as Hormones

I. Natural Steroid Hormones (All implants used to promote growth, with no withdrawal time)
   - A. *Compudose*. Contains 24 mg estradiol; for all cattle.
   - B. *Heiferoid*. Contains 20 mg estradiol benzoate and 200 mg testosterone propionate; for heifers >400 lb (182 kg).
   - C. *Steeroid*. Contains 20 mg estradiol benzoate and 100 mg progesterone; for steers >400 lb (182 kg).
   - D. *Synovex C*. Contains 10 mg estradiol benzoate and 100 mg progesterone; for calves <400 lb (182 kg).
   - E. *Synovex H*. Contains 20 mg estradiol benzoate and 200 mg testosterone propionate; for heifers >400 lb (182 kg).
   - F. *Synovex S*. Contains 20 mg estradiol benzoate and 200 mg progesterone; for steers >400 lb (182 kg).

II. Synthetic Steroid-like Hormones (All implants used to promote rate of growth, with no withdrawal time)
   - A. *Finaplix S*. Containns 140 mg trenbolone acetate; for steers >400 lb (182 kg).
   - B. *Finaplix H*. Contains 200 mg trenbolone acetate; for heifers >400 lb (182 kg).
   - C. *Revalor*. Contains 120 mg trenbolone acetate and 24 mg estradiol; for cattle >600 lb (273 kg).

III. Nonsteroid anabolic agent (Implant used to promote rate of growth, with no withdrawal time)
   Ralgro. Contains 36 mg zeranol; for all ages and both sexes of cattle.

IV. Feed Additive, Hormone-like
   Melengestrol Acetate. Fed at level of 0.25 to 0.50 mg per head, daily, to increase rate of gain, improve feed efficiency, and suppress estrus in heifers fed for slaughter. Must be withdrawn 48 h before slaughter.

Compounds, Levels, and Purposes of Use When Used in Feeds for Cattle

Compound	Level	Purpose
Amprolium. (Amprol 25%, Amprol Plus, Amprovine 25%)	Beef and dairy calves; 227 mg per 100 cwt (45 kg)/day for 21 days; 454 g/cwt (45 kg) per day for 5 days	Aid in prevention of coccidiosis; withdraw 24 h before slaughter. Aid in treatment of coccidiosis.
Bacitracin Methylene Disalicylate (BMD, Fortracin)	Feedlot beef cattle; 70 mg/day, or 250 mg/day for 5 days	Reduction in liver abscesses.
Bacitracin Zinc (Albac 50, Baciferm)	Cattle, growing 35–70 mg/head/day	Increased weight gain, improved feed efficiency.
Chlortetracycline (Aureomycin, CLTC, etc.)	Calves less than 250 lb(114 kg); 0.1 mg/lb (454 g) per day	Growth promotion and feed efficiency.
Beef cattle and nonlactating dairy cattle		
	25 to 70 mg/day	Growth promotion and increased feed efficiency; decreased liver abscesses. For

TABLE AI (*Continued*)

Compound	Level	Purpose
		cattle under 700 lb (318 kg), prevention of bacterial diarrhea and footrot.
	100 mg/day	Cattle over 700 lb (318 kg), for prevention of bacterial diarrhea and footrot.
	350 mg/day	Prevention of bacterial pneumonia and shipping fever losses due to respiratory infections and aid in prevention of anaplasmosis for cattle up to 700 lb (318 kg). Discontinue use 48 h before slaughter.
Beef cattle and nonlactating dairy cattle, for aid in prevention of anaplasmosis. Discontinue use 48 h before slaughter.		
	500 mg/hd/day	For cattle weighing 700 to 1000 lb (318 to 454 kg)
	750 mg/head/day	For cattle weighing 1000 to 1500 lb (454 to 682 kg).
	0.5 mg/lb (454 g)/day	For cattle weighing over 1500 lb (682 kg).
Chlortetracycline, plus *Sulfamethazine* (Aureo S-700)	350 mg/head/day, each	For beef cattle; feed for 28 days to aid in maintaining weight gain in presence of respiratory disease and shipping fever. Discontinue 7 days before slaughter.
Coumaphos (Meldane, Baymix)	0.091 g/cwt (45 kg), 6 days	Control of gastrointestinal roundworms. Do not use for animals under 3 months of age, or for animals under stress, or in combination with phenothiazine.
Decoquinate (Decox)	22.7 mg/cwt (45 kg), for 28 days	Prevention of coccidiosis.
Fenbendazole (Safe-Guard)	2.27 mg/lb (45 g) body weight, over 1 to 6 days	Removal and control of lung, stomach, and intestinal worms. Do not use within 13 days of slaughter.
Lasalocid (Bovatec)	10 to 30 g/ton (0.9 Mton) total ration to provide 100–360 mg/head/day	Improve feed efficiency of cattle fed in confinement for slaughter.

(*continues*)

TABLE AI (*Continued*)

Compound	Level	Purpose
	25 to 30 g/ton (0.9 Mton) to provide 250–360 mg/head/day	Improve feed efficiency and increase weight gain of cattle fed in confinement for slaughter.
	60 to 200 mg/head/day in at least 1 lb (454 g) feed or in an approved free choice formulation	Increased weight gain with pasture cattle (slaughter, stocker, feeder cattle, beef and dairy replacement heifers).
	1 mg/2.2 lb (kg) body weight. Maximum 360 mg/day for cattle up to 800 lb (364 kg)	Control coccidiosis.
Lasalocid	10–30 or 25–30 g/ton (0.9 Mton) feed	Improved feed efficiency and weight gain of cattle fed in confinement for slaughter.
plus		
Oxytetracycline	7.5 g/ton (0.9 Mton) ration to provide 75 mg/head/day	
Lasalocid	100–360 mg/head/day	Increase weight gain and feed efficiency of heifers.
plus		
Melengestrol acetate (MGA)	0.25 to 0.5 mg/head per day	Suppression of estrus in heifers fed in confinement for slaughter. Withdraw MGA 48 h before slaughter.
Lasalocid	100–360 mg/head/day	Increased weight gain and feed efficiency.
plus		
Melengestrol acetate	0.25–0.50 mg/head/day	Suppression of estrus in heifers fed in confinement for slaughter. Withdraw MGA 48 h before slaughter.
plus		
Tylosin	90 mg/head/day	Reduce liver abscesses.
Levamisol hydrochloride (Tramisol)	0.08 to 0.8% (0.36–3.6 g) per cwt (45 kg)	Treating cattle infected with gastrointestinal worms and lung worms.
Melengestrol acetate (MGA)	0.25–0.50 mg/head per day	For increased rate of gain, improved feed efficiency, and suppression of estrus in heifers fed for slaughter. Withdraw MGA 48 h before slaughter.
Methoprene (Altosid)	22.7–45.4 mg per cwt (45.4 kg) body weight/month	Prevent the breeding of horn in the manure of cattle

TABLE AI (*Continued*)

Compound	Level	Purpose
Monensin (Rumensin)	5 to 30 g/ton (0.9 Mton) ration to provide 50 to 360 mg/head/day	Improved feed efficiency of beef cattle fed in confinement for slaughter.
	10 to 30 g/ton (0.9 Mton) ration to provide 100 to 360 mg/head/day	Prevention and control of coccidiosis for cattle in confinement.

Slaughter, stocker, feeder dairy, and beef replacement heifers weighing more than 400 lb (206 kg), on pasture, for increased gain, but restricted as follows: 25 to 400 g/ton (0.9 Mton) of supplement to provide 50 to 200 mg/day in not less than 1 lb (454 g) of feed, or after 5 days, 400 mg/hd, every other day in not less than 2 lb (908 kg) of feed. Feed only 100 mg/day first 5 days. 50–200 mg/head/day in minimum of 1 lb (454 g) of feed; during first 5 days feed no more than 100 mg per day—do not self-feed. Will improve feed efficiency—feed can be restricted to 95% of normal requirement when 50 mg is fed and to 90% at 200 mg.

Compound	Level	Purpose
Monensin plus	5 to 30 g/ton (0.9 Mton) feed or 50–1200 g to provide 50–360 per day	For increased gain and improved feed efficiency and suppression of estrus in heifers fed for slaughter. Withdraw MGA 48 h before slaughter.
Melengestrol acetate (MGA)	0.25 to 0.40 mg/head per day	
Monensin	5–30 g/ton (0.9 MTon)	Improve feed efficiency and reduce liver abscesses.
plus		
tylosin	8–10 g/ton (0.9 Mton)	
Monensin plus	50–360 mg/head/day	Increased rate of gain; improved feed efficiency; suppression of estrus in heifers fed for slaughter. Reduced liver abscesses.
Melengestrol acetate plus	0.25–0.50 mg/head/day	
Tylosin	90 mg/head/day	Discontinue MGA 48 h before slaughter.
Moratel tartrate	0.44 g/100 lb (45 kg)	For removal and control of mature gastrointestinal nematode infection and worms. Do not treat within 14 days of slaughter.
Oxytetracycline (Terramycin, OXTC)	Calves 0–12 week: 0.05–0.1 mg/lb (454 g) body weight/day	Improved rate of gain and feed efficiency. Withdraw 5 days before slaughter.
	0.5 mg/lb (454 g) body weight per day	Prevent bacterial diarrhea in milk replacers and starter

(*continues*)

TABLE AI (*Continued*)

Compound	Level	Purpose
		feeds. At 2 g/head/day, withdraw 5 days before slaughter.
	25–75 mg/head/day	Increase rate of gain and feed efficiency of calves.
	50 g/ton (0.9 Mton)	Prevent bacterial diarrhea of calves.
	100 g/ton (0.9 Mton)	Treatment of bacterial diarrhea in calves.
	75 mg/head/day	Increase rate of gain and feed efficiency of finishing beef cattle; reduce liver abscesses.
	0.1–0.5 mg/lb (454 g) body weight/day	Prevent bacterial diarrhea in in cattle.
	0.5–5.0 mg/lb (454 g) body weight/day	Treatment of bacterial diarrhea in cattle.
	0.5–2.0 g/head/day	Prevention and treatment of shipping fever when fed 3–5 days preceding and/or following arrival into feedlots.
Oxytetracycline plus	75 mg/head/day	Aid in reducing liver abscesses and improved feed efficiency and weight gain.
Lasalocid	10–30 or 25–30 g/ton (0.9 Mton) complete feed to provide 100 to 360 mg/head/day	
Poloxalene	1–2 g/cwt (45 kg)	Prevention of legume and wheat pasture bloat.
Propylene glycol	025–0.5 lb (113–227 g) 2 weeks before or 6 weeks after calving	Prevention of ketosis.
	0.25–1 lb (113–454 g) for 10 days	Treatment of ketosis.
Rabon	0.07 g/cwt (45 kg) per day	Prevention of development of flies in manure of treated cattle.
Thiabendazole	0.3–5 g/cwt (45 kg)	Control of gastrointestinal roundworms. Do not treat within 30 days of slaughter.
Tylosin	8–10 g/ton (0.9 Mton) feed to 60–90 mg/head/day	Reduce liver abscesses in cattle.

Appendix II

How Much Can I Afford to Pay for Feeder Cattle?

David C. Petritz and Kern S. Hendrix

How much can I afford to pay for feeder cattle? It is good business, always, to estimate the prospects for making a profit before investing in a cattle feeding venture.

Even though one may peruse the various futures markets with the greatest of care, one cannot know what the sale price for finished cattle will be—unless of course one is locked-in on a contract sale. However, barring any unanticipated environmental disasters, one can determine the sale price necessary to recover the cost of the animal plus feed and other costs of production. This price is, of course, the "break-even" selling price, and provides a value to compare with the future cattle selling price predictions. This then provides a benchmark, helping the cattle feeder to decide whether to purchase a particular group of feeder cattle or await alternative opportunities.

This section provides data and techniques for arriving at production costs and break-even selling prices for 10 alternative cattle feeding programs. Table AII.1 describes the 10 systems considered; Tables AII.2 and AII.3 present the necessary returns and costs for each system. Table AII.4 presents information for determining the price of corn silage for alternative prices of corn and corn silage. Tables AII.5 through AII.14 list the selling prices necessary to cover cost of the animals, feed, and other variable and fixed costs for different combinations of feed and feeder cattle prices.

The 10 feeding systems are presented for illustrative purposes only. Table AII.15 is a budget form which is provided to help estimate the production costs and the necessary selling prices for each of several feeding programs.

TABLE AII.1
Approximate Feed Requirements and Rates of Gain for Alternative Cattle Feeding Programs under Average Feedlot Conditions

Frame size: Age at purchase: Sex:	Medium Calf Steer	Medium Calf Steer	Medium Yearling Steer	Large Calf Steer	Medium Calf Heifer	Large Calf Heifer	Medium Calf Stocker	Holstein Calf Steer	Holstein Calf Steer	Holstein Yearling Steer
Feeding program	1	2	3	4	5	6	7	8	9	10
Purchase weight										
lb	500	500	700	500	450	500	500	450	450	800
kg	227	227	318	227	205	227	227	205	205	364
Purchase shrink (%)	5	5	5	5	5	5	5	5	5	5
Selling weight										
lb	1100	1080	1150	1200	880	1000	700	1060	1060	1250
kg	500	482	523	545	400	454	318	482	482	568
Sale shrink (%)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Days on farm	265	220	160	235	220	220	160	230	210	170
Corn										
bu	37	45	37	56	40	45	0	47	53	70
kg	942	1145	942	1425	1018	1145	0	1196	1349	1782
Corn silage										
Ton	3.5	1.8	2.0	2.25	1.5	1.8	0	2	0	0
Metric ton	3.2	1.6	1.8	2.0	1.4	1.6	0	1.8	0	0
Pasture										
Acres	0	0	0	0	0	0	1	0	0	0
Hectare	0	0	0	0	0	0	0.4	0	0	0
Suppl.,40%										
lb	310	275	175	350	250	250	0	300	290	90
kg	141	125	80	159	114	114	0	136	132	41
Hay										
lb	200	200	200	200	200	200	200	200	1200	500
kg	91	91	91	91	91	91	91	91	545	227

Daily gain										
lb	2.26	2.55	2.81	2.98	1.95	2.27	1.25	2.65	2.90	2.64
kg	1.03	1.16	1.29	1.35	0.89	1.03	0.57	1.20	1.32	1.20

Animal weights shown are considered to be payweights at purchase and selling; thus, when a feedlot operator proposes cattle are gaining at a weight of greater then 3 lb per day (1.36 kg/day), this may represent periodic gains from the time cattle were started on feed rather than their gain from purchase weight. Arrival weights in the feedlot normally are assumed to be 5% less than payweights and sale weights normally are assumed to be at least 3.5% less than actual feedlot finish weights. Therefore, when shrinkage both at the purchase end and at the finish end are taken into account "payweight to payweight" gain must be considerably less than periodic wight gains. In other words, once newly arrived cattle get over their shipping stress, their first 28-day gain may be unrealistically high.

Feed requirements are given on an as-fed basis: corn grain and hay, 85% dry matter; corn silage, 35% dry matter; supplement, 90% dry matter. Legume hay or haylage may be substituted into these rations. Five hundred and fifty pounds (250 kg) of legume hay or 1000 lb (454 kg) of haylage (16% protein) plus 7 bushels (178 kg) of corn grain can replace 1 ton (0.9 metric ton) of corn silage and 125 lb (57 kg) of 40% protein supplement.

Systems 1 to 6 are based upon corn grain, corn silage and 40% protein supplement. Feed consumption and performance levels are based on information from the National Research Council (1984), Nutrient Requirements of Beef Cattle, sixth revised edition. Approximately 5% has been added to actual feed requirements to account for spoilage and feed wastage. No attempt was made to account for the effects of weather, lot condition, facilities, or management upon animal performance.

System 1 is designed for those producers with an abundant supply of silage. In this system only corn silage and supplement are fed for 90 days or until cattle weigh approximately 700 lb (318 kg). Following this there is a gradual step-up in level of grain corn to a 1:1 ratio of silage to corn grain on an as-fed basis. This ratio is maintained until the cattle reach slaughter grade and weight. Level of supplement feeding remains constant throughout.

For systems 2 through 6, following acclimation, cattle are started on a 4:1 silage to grain ration, as fed, and adjusted gradually such that in 90 days cattle are receiving a 1:1 ratio of silage to grain. Protein supplement is fed initially at from 1.5 to 2 lb daily (0.7 to 0.9 kg), for large frame calves, and gradually reduced to a final level of 1 lb daily (0.45 kg) as the cattle reach 800–900 lb (364–409 kg).

System 7 utilizes only pasture and minerals except for some hay during acclimation. The daily gain is an indicator of the quality of the pasture. For fescue pastures infected with the endophyte fungus, daily gain will be decreased. Grain supplementation of pasture will increase daily gain approximately 0.10 lb (45 g) for each 1 lb (454 g) of grain fed up to a level of 4 lb daily (1.8 kg), at which level gain response to level of grain fed becomes less pronounced. The use of an ionophore (monensin or lasalocid) plus growth stimulants can enhance daily gains 0.20 lb (90 g) or more per day.

Systems 8 through 12 are for Holstein calves. In system 8, corn silage should be fed at no more than 55% of the ration dry matter (3:1 silage:grain as fed) to 750 lb (341 kg) body weight, and at no more than 30% of dry matter (1:1 silage:grain as fed) beyond 750 lb (341 kg) body weight. Systems 9 and 10 are based on concentrate to dry hay ratios (as fed) of 3:1 and 9:1, respectively.

All cattle are assumed to be implanted (or fed as in the case of heifers fed melengesterol acetate) at prescribed levels with effective and legal growth stimulants. If a growth stimulant is not used, daily gains should be calculated as approximately 10% lower, and feed requirements per unit gain should be increased accordingly. Proper use of an ionophore can result in 10% less dry matter consumption and can result in a 10% improvement in efficiency of feed utilization.

TABLE AII.2

Approximate Production Costs and Necessary Returns for 10 Alternative Cattle Feeding Programs

	Feeding program choice (see Table AII.1)									
	1	2	3	4	5	6	7	8	9	10
Market weight (Pay wt)										
lb	1078	1039	1139	1176	862	980	686	1039	1039	1238
kg	490	472	518	534	445	392	312	472	472	563
A. Purchase cost ($)										
500 lb @ $0.90	450	450								
227 kg @ 1.98	450	450								
700 lb @ 0.80			560							
318 kg @ 1.76			560							
500 lb @ 0.90				450						
227 kg @ 1.98				450						
450 lb @ 0.85					382					
204 kg @ 1.87					382					
500 lb @ 0.85						425				
227 kg @ 1.87						425				
500 lb @ 0.90							450			
227 kg @ 1.98							450			
450 lb @ 0.80								360	360	

204 kg @ 1.76								360	360	
800 lb @ 0.70										560
364 kg @ 1.54										560
B. Cost of feed/head ($) Corn, $2/bu, 7.8¢/kg; corn sil., $19/ton, $20.35/Mton; Suppl., $15 per cwt., 33¢ per kg; hay, $60/ton, $66.60/Mton	203	184	157	229	164	181	13.80	196	206	194
C. Variable costs ($) i.e., death, vet., interest, gas, oil, repairs, market costs	103	93	82	99	88	92	63	90	87	86.40
D. Fixed costs ($), i.e, labor, bldgs., equip., machinery, deprec.	100	100	74	100	100	100	40.50	100	100	74
Total costs	856	827	873	878	734	798	567.30	746	753	914.40
E. Selling price needed ($)										
1. For feed and variables										
per cwt	70.19	70.05	70.05	66.35	73.73	71.37	76.82	62.19	62.84	67.87
per kg	1.54	1.50	1.50	1.46	1.62	1.57	1.69	1.37	1.37	1.49
2. For total costs										
per cwt	79.41	79.68	76.65	74.65	85.33	81.37	82.72	71.82	72.47	73.85
per kg	1.65	1.80	1.69	1.64	1.87	1.79	1.81	1.58	1.60	1.62

TABLE AII.3

Breakdown of Variable Costs for 10 Alternative Cattle Feeding Programs (Dollars per Animal)

	Feeding program choices (See Table AII.1)									
	1	2	3	4	5	6	7	8	9	10
Veterinary and medicine	15	15	12	15	15	15	10	15	15	12
Marketing costs[a]	20	20	22.50	20	20	20	20	20	20	22.50
Power, fuel, repairs	13	13	10	13	13	13	7.50	13	13	10
Interest, insurance, taxes on feed and cattle[b]	52	42	35	48	37	41	23	39	36	39.40
Miscellaneous	3	3	2.50	3	3	3	2.50	3	3	2.50
Total variable costs	103	93	82	99	88	92	63	90	87	86.40

[a]Includes commission cost of purchasing feeder animals and hauling to feedlot, and commission cost of marketing fed animal plus hauling to market.

[b]Equal to 11% (0.11) times the following: purchase price of the animal plus value of corn fed plus value of corn silage fed plus value of hay fed plus one-half the value of purchased supplement (purchased from month to month), salt and mineral fed. This total value then is multiplied by the fraction of 365 days that is in the feeding period.

TABLE AII.4

Approximate Value of Corn Silage at Various Dry Matter Contents, at Various Prices for Corn Grain

English system				Metric system			
Corn price per bushel, No. 2 basis	Dry matter content (%) 30	35	40	Corn price per kilogram, No. 2 basis	Dry matter content (%) 30	35	40
	Value per ton (English)[a]				Value per metric ton[b]		
$1.70	$13.25	$14.80	$16.35	6.7¢	$14.85	$15.95	$17.88
1.80	13.80	15.45	17.05	7.1	15.18	17.00	18.78
1.90	14.35	16.05	17.80	7.5	15.78	17.65	19.58
2.00	14.90	16.70	18.50	7.9	16.39	18.37	20.35
2.10	15.45	17.35	19.25	8.2	17.00	19.08	21.18
2.20	16.00	17.95	19.95	8.6	17.60	19.74	21.94
2.30	16.55	18.60	20.70	9.0	18.20	20.46	22.77
2.40	17.10	19.25	21.40	9.4	18.81	21.18	23.54
2.50	17.65	19.90	22.15	9.8	19.41	21.89	24.36
2.60	18.15	20.50	22.85	10.2	19.96	22.55	25.14
2.70	18.70	21.15	23.60	10.6	20.57	23.26	25.96
2.80	19.25	21.80	24.30	11.0	21.17	23.98	26.73
2.90	19.80	22.40	25.05	11.4	21.78	24.64	27.56
3.00	20.35	23.05	25.75	11.8	22.38	25.35	28.32
3.10	20.90	23.70	26.50	12.2	22.99	26.07	29.15
3.20	21.45	24.30	27.20	12.6	23.60	26.73	29.92
3.30	21.90	24.90	27.90	13.0	24.09	27.39	30.69

[a]Value of English ton of silage is based on following amounts of corn grain for different dry matter contents: 5.45 bu/ton 30% dm, 6.35 bu/ton 35% dm, 7.25 bu/ton 40% dm.

[b]Value of Metric ton of silage is based on following amounts of corn grain for different dry matter contents: 152.6 kg/ M ton at 30% dm; 175 kg/ M ton at 35% dm; 203 kg/ M ton at 40% dm.

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The 10 feeding systems are presented for illustrative purposes only. Table AII.15 is a budget form which is provided to help estimate the production costs and the necessary selling prices for each of several feeding programs.

TABLE AII.6

Sensitivity Analysis for Medium-Frame Steer Calf Fed High-Grain Ration (Program 2)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb				
	$81.00	$85.50	$90.00	$94.50	$99.00
$67.50	21.46	−2.54	−26.53	−50.52	−74.51
71.25	60.41	36.42	12.43	−11.56	−35.56
75.00	99.37	75.37	51.38	27.39	3.40
78.75	138.32	114.33	90.34	66.35	42.35
82.50	177.28	153.28	129.29	105.03	81.31

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed prices per 100 lb gain				
	$30.81	$32.52	$34.23	$35.94	$37.65
$81.00	73.18	74.12	75.06	76.00	76.94
85.50	75.49	76.43	77.37	78.31	79.25
90.00	77.80	78.74	79.68	80.62	81.56
94.50	80.11	81.05	81.99	82.93	83.87
99.00	82.42	83.36	84.30	85.24	86.18

Break-even selling prices required to pay only direct charges would be $9.63 less than the above figures.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain				
	$30.81	$32.52	$34.23	$35.94	$37.65
$67.50	69.93	68.10	66.27	64.44	62.60
71.25	77.24	75.41	73.57	71.74	69.91
75.00	84.54	82.71	80.88	79.05	77.22
78.75	91.85	90.02	88.19	86.36	84.52
82.50	99.16	97.33	95.49	93.66	91.83

Break-even prices required to pay only direct charges would be $18.76 more than those shown above.

TABLE AII.7

Sensitivity Analysis for Medium-Frame Yearling Steer Fed High-Grain Ration (Program 3)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb: $72.00	$76.00	$80.00	$84.00	$88.00
$67.50	28.57	−0.78	−30.13	−59.48	−88.83
71.25	71.26	41.91	12.56	−16.79	−46.14
75.00	113.96	84.61	55.26	25.91	−3.44
78.75	156.65	127.30	97.95	68.60	39.25
82.50	199.34	169.99	140.64	111.39	81.94

In order to make the desired payments for overhead and labor, this return must be at least $74 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain: $32.15	$33.93	$35.72	$37.50	$39.29
$72.00	70.05	70.77	71.49	72.21	72.93
76.00	72.63	73.35	74.07	74.79	75.50
80.00	75.21	75.93	76.65	77.36	78.08
84.00	77.79	78.51	79.22	79.94	80.66
88.00	80.37	81.08	81.80	82.52	83.24

Break-even selling prices required to pay only direct charges would be $6.50 less than those shown above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain: $32.15	$33.93	$35.72	$37.50	$39.29
$67.50	68.04	66.92	65.81	64.69	63.58
71.25	73.86	72.74	71.63	70.51	69.40
75.00	79.67	78.56	77.45	76.33	75.22
78.75	85.49	84.38	83.25	82.15	81.04
82.50	91.31	90.20	89.08	87.97	86.85

Break-even prices required to pay only direct charges would be $10.09 more than those shown above.

TABLE AII.8

Sensitivity Analysis for Large-Frame Steer Calf Fed High-Grain Ration (Program 4)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb $81.00	$85.50	$90.00	$94.50	$99.00
$67.50	61.73	37.64	13.54	−10.55	−34.64
71.25	105.83	81.74	57.64	33.55	9.46
75.00	149.93	125.84	101.74	77.65	53.56
78.75	194.03	169.94	145.84	121.75	97.66
82.50	238.13	214.04	189.94	165.85	141.76

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain $30.51	$32.21	$33.90	$35.60	$37.29
$81.00	68.68	69.72	70.75	71.79	72.83
85.50	70.73	71.77	72.80	73.84	74.87
90.00	72.78	73.82	74.85	75.89	76.92
94.50	74.83	75.86	76.90	77.94	78.97
99.00	76.88	77.91	78.95	79.98	81.02

Break-even selling prices required to pay only direct charges would be $8.50 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain $30.51	$32.21	$33.90	$35.60	$37.29
$67.50	78.40	76.13	73.58	71.58	69.30
71.25	86.64	84.36	82.09	79.81	77.54
75.00	94.87	92.60	90.33	88.05	85.78
78.75	103.11	100.84	98.56	96.29	94.01
82.50	111.35	109.07	106.80	104.52	102.25

Break-even prices required to pay only direct charges would be $18.68 more than those listed above.

TABLE AII.9

Sensitivity Analysis for Medium-Frame Heifer Calf Fed High-Grain Ration (Program 5)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb: $76.50	$80.75	$85.00	$89.52	$93.50
$67.50	−12.94	−33.33	−53.72	−74.12	−94.51
71.25	19.40	−0.99	−21.38	−41.78	−62.71
75.00	75.00	51.74	10.96	−9.44	−29.53
78.75	84.08	63.69	43.30	22.90	2.51
82.50	116.42	96.03	75.64	55.24	34.85

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain: $35.72	$37.70	$39.68	$41.67	$42.65
$76.50	78.59	79.59	80.60	81.60	82.61
80.75	80.95	81.96	82.96	83.97	84.97
85.00	83.32	84.32	85.33	86.33	87.33
89.25	85.68	86.69	87.69	88.69	89.70
93.50	88.05	89.05	90.05	91.06	92.06

Break-even selling prices required to pay only direct charges would be $11.60 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain: $35.72	$37.70	$39.68	$41.67	$42.65
$67.50	56.57	54.77	52.96	51.16	49.35
71.25	63.31	61.51	59.70	57.90	56.09
75.00	70.05	68.25	66.44	64.64	62.83
78.75	76.79	74.99	73.18	71.38	69.57
82.50	83.53	81.73	79.92	78.12	76.31

Break-even prices required to pay only direct charges would be $20.84 more than those listed above.

TABLE AII.10

Sensitivity Analysis for Large-Frame Heifer Calf Fed High-Grain Ration (Program 6)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb $76.50	$80.75	$85.00	$89.25	$93.50
$67.50	7.42	−15.24	−37.90	−60.56	−83.21
71.25	44.17	21.51	−1.15	−23.81	−46.46
75.00	80.92	58.26	35.60	12.94	−9.71
78.75	117.67	95.01	72.35	49.69	27.04
82.50	154.42	131.76	109.10	86.44	63.79

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain $33.89	$35.78	$37.66	$39.54	$41.42
$76.50	74.99	75.97	76.95	77.92	78.90
$80.75	77.30	78.28	79.26	80.24	81.21
$85.00	79.62	80.59	81.57	82.55	83.53
$89.25	81.93	82.91	83.88	84.86	85.84
$93.50	84.24	85.22	86.20	87.17	88.15

Break-even selling prices required to pay only direct charge would be $10.20 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain $33.89	$35.78	$37.66	$39.54	$41.42
$67.50	62.73	60.93	59.14	57.34	55.54
71.25	69.62	67.82	66.03	64.23	62.44
75.00	76.51	74.72	72.92	71.13	69.33
78.75	83.41	81.61	79.81	78.02	76.22
82.50	90.30	88.50	86.71	84.91	83.12

Break-even prices required to pay only direct charges would be $18.67 more than those listed above.

TABLE AII.11

Sensitivity Analysis for Medium-Frame Stocker Calf on Growth Program (Program 7)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb				
	$81.00	$85.50	$90.00	$94.50	$99.00
$72.00	14.13	−9.46	−33.04	−56.63	−80.21
76.00	41.57	17.98	−5.60	−29.19	−52.72
80.00	69.01	45.42	21.84	−1.75	−25.33
84.00	96.45	72.86	49.28	25.69	2.11
88.00	123.89	100.30	76.72	53.13	29.55

In order to make the desired payments for overhead and labor, this return must be at least $40.50 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain				
	$6.68	$7.05	$7.42	$7.79	$8.16
$81.00	75.63	75.74	75.84	75.95	76.05
85.50	79.07	79.18	79.28	79.39	79.49
90.00	82.51	82.62	82.72	83.83	82.93
94.50	85.95	86.05	86.16	86.26	86.37
99.00	89.39	89.49	89.60	89.70	89.81

Break-even selling prices required to pay only direct charges would be $5.90 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain				
	$6.68	$7.05	$7.42	$7.79	$8.16
$72.00	76.24	76.11	75.97	75.83	75.69
76.00	81.48	81.34	81.20	81.07	80.93
80.00	86.71	86.58	86.44	86.30	86.16
84.00	91.95	91.81	91.68	91.54	91.40
88.00	97.19	97.05	96.91	96.77	96.64

Break-even prices required to pay only direct charges would be $7.73 more than those listed above.

TABLE AII.12

Sensitivity Analysis for Holstein Steer Calf Fed Silage plus Corn Ration (Program 8)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb $72.00	$76.00	$80.00	$84.00	$88.00
$63.00	46.83	27.58	8.33	−10.91	−30.16
66.50	83.19	63.94	44.69	25.44	6.20
70.00	119.54	100.34	81.05	61.80	42.55
73.50	155.90	136.65	117.41	98.16	78.91
77.00	192.26	173.01	153.76	134.52	115.27

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain $30.03	$31.69	$33.36	$35.03	$36.70
$72.00	66.11	67.11	68.12	69.12	70.13
76.00	67.96	68.97	69.97	70.98	71.98
80.00	69.82	70.82	71.82	72.83	73.83
84.00	71.67	72.67	73.68	74.68	75.68
88.00	73.52	74.53	75.53	76.53	77.54

Break-even selling prices required to pay only direct charges would be $9.63 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain $30.03	$31.69	$33.36	$35.03	$36.70
$63.00	85.28	83.12	60.95	58.78	56.62
66.50	72.84	70.67	68.51	66.34	64.17
70.00	80.40	78.23	76.06	73.89	71.73
73.50	87.95	85.78	83.62	81.45	79.26
77.00	95.51	93.34	91.17	89.01	86.83

Break-even prices required to pay only direct charges would be $20.78 more than those listed above.

TABLE AII.13

Sensitivity Analysis for Holstein Steer Calf Fed Hay plus Corn (Program 9)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb $72.00	$76.00	$80.00	$84.00	$88.00
$63.00	39.92	20.78	1.65	−17.49	−36.63
66.50	76.28	57.14	38.00	18.86	−0.27
70.00	112.64	93.50	74.36	55.22	36.08
73.50	149.00	129.86	110.72	91.58	72.44
77.00	185.36	166.22	147.08	127.94	108.80

In order to make the desired payments for overhead and labor, this return must be at least $100.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain $31.46	$33.21	$34.96	$36.71	$38.46
$72.00	66.69	67.74	68.78	69.83	70.88
76.00	68.53	69.58	70.63	71.67	72.72
80.00	70.37	71.42	72.47	73.52	74.56
84.00	72.22	73.26	74.31	75.36	76.40
88.00	74.06	75.11	76.15	77.20	78.25

Break-even selling prices required to pay only direct charges would be $9.63 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain $31.46	$33.21	$34.96	$36.71	$38.46
$63.00	63.99	61.72	59.44	57.17	54.90
66.50	71.59	69.32	67.04	64.77	62.50
70.00	79.19	76.91	74.64	72.37	70.10
73.50	86.79	84.51	82.24	79.97	77.69
77.00	94.39	92.11	89.84	87.57	85.29

Break-even prices required to pay only direct charges would be $20.90 more than those listed above.

TABLE AII.14

Sensitivity Analysis for Holstein Yearling Steer Fed Hay plus Corn (Program 10)

A. Return to overhead, labor, and management per head ($)

Selling price/cwt	Purchase price per 100 lb $63.00	$66.50	$70.00	$73.50	$77.00
$63.00	−1.45	−30.89	−60.32	−89.76	−119.19
66.50	41.86	12.42	−17.01	−46.45	−75.88
70.00	85.17	55.74	26.30	−3.13	−32.57
73.50	128.48	99.05	69.61	40.18	10.74
77.00	171.80	142.36	112.93	83.49	54.06

In order to make the desired payments for overhead and labor, this return must be at least $74.00 per head.

B. Break-even selling prices required to pay all expenses ($/cwt)

Purchase price/cwt	Feed costs per 100 lb gain $39.81	$42.03	$44.24	$46.45	$48.66
$63.00	67.46	68.28	69.10	69.92	70.74
66.50	69.83	70.66	71.48	72.30	73.12
70.00	72.21	73.03	73.85	74.68	75.50
73.50	74.59	75.41	76.23	77.05	77.87
77.00	76.97	77.79	78.61	79.43	80.25

Break-even selling prices required to pay only direct charges would be $5.98 less than those listed above.

C. Break-even purchase prices required to pay all expenses ($/cwt)

Selling price/cwt	Feed costs per 100 lb gain $39.81	$42.03	$44.24	$46.45	$48.66
$63.00	56.44	55.24	54.03	52.82	51.61
66.50	61.59	60.39	59.18	57.97	56.76
70.00	66.74	65.54	64.33	63.12	61.91
73.50	71.89	70.69	69.48	68.27	67.06
77.00	77.04	75.84	74.63	73.42	72.21

Break-even prices required to pay only direct charges would be $4.40 more than listed above.

TABLE AII.15

Budget Form for Estimating Your Own Break-Even Selling Price for Cattle

			Costs per head		Costs per head	
1. Purchase price	______ lb	@ ______ /lb =		______		______
2. Feed cost						
a. Corn	______ bu	@ ______/bu =	______		______	
b. Corn silage	______ tons	@ ______/ton =	______		______	
c. Supplement	______ lb	@ ______/lb =	______		______	
d. Other	______	@ ______/	______		______	
e. Other	______	@ ______/	______		______	
Total feed cost				______		______
3. Other variable costs						
a. Veterinary and medicine			______		______	
b. Death loss (2% of Line 1 for calves, 1% for yearlings)			______		______	
c. Marketing, commission charges, trucking expenses[a]			______		______	
d. Power, fuel, equipment repair[b]			______		______	
e. Interest, insurance, taxes on feed and cattle[c]			______		______	
f. Miscellaneous			______		______	
Total variable cost				______		______
4. Fixed costs						
a. Buildings and equipment[d]			______		______	
b. Labor	______ hr	@ ______/hr[e]	______		______	
Total fixed cost			______		______	

(*continues*)

TABLE AII.15 *(Continued)*

	Costs per head		Costs per head	
5. Total of all costs (1 + 2 + 3 + 4)				______
6. Necessary selling price to return	Total cost per head	Necessary selling price per cwt[f]	Total cost per head	Necessary selling price per cwt[f]
Cost of feeder and feed costs (1 + 2)	______	______	______	______
All variable costs (1 + 2 + 3)	______	______	______	______
All costs (1 + 2 + 3 + 4)	______	______	______	______

[a]Include commission cost of purchasing feeder animal and hauling to farm, and commission cost of marketing fed animal and hauling to market.

[b]Power, fuel, and equipment repair costs are estimated to be \$5–8 per head.

[c]Equal to 10.0% (0.10) times the following: purchase price of steer plus value of corn fed plus value of corn silage fed plus one-half of the value of supplement, salt, and mineral fed. This value is then multiplied by the fraction of the year that is in the feeding period.

[d]Equal to 14% (0.14) of the current investment in shelter, silage storage, and feed handling and other equipment associated with the cattle feeding enterprise. It is assumed that storage for corn is included in the price of corn.

[e]Estimated to be 3–6 hours per head typically with long-fed cattle requiring the larger amount.

[f]Divide costs per head by market weight (pay weight) per head.

Appendix III

Some Current Specifications for Beef Cattle Equipment

Temple Grandin

Specifications

Housed resting space, square ft/head (square m/ head)
Mature cows, 30 to 35 (2.8 to 3.3)
Calves to 600 lb (273 kg), 15 to 20 (1.4 to 1.9)
Feeder cattle, 600 lb to market (273 kg), 20 to 25 (1.9 to 2.3)
Shade
20 to 25 square ft/head (1.9 to 2.3 square m)
10 ft (3.1 m)
North–South orientation
Provided over bunk, in open shed, or under separate shades

Additional Space

Total recommended feedlot space usually exceeds the total required for feeding, resting, and shade. Year-round access must be provided to the above three areas and the working areas. Total additional space depends upon drainage, snow drifting (whether some space will be available for portions of the year), tradition, etc. The following figures should be compared with local conditions and experience. The approximate space (add up to 50% for wet or severe climates) in square feet per head (square meters per head) is given below.

	Shed or loafing		Paved feed		Open yard	
	Square feet	Square meters	Square feeding	Square meters	Square feet	Square meters
Cows	25–40	2.4–3.7	—	—	150–250	14–23
Yearlings	20–30	1.9–2.8	20–30	1.9–2.8	100–175	9–16
Calves	15–25	1.4–2.3	15–25	1.4–2.3	75–125	7–12

If yard conditions are muddy, open yard requirements should be increased at least 50%.

Topography

Uniform 4–6% slope away from prevailing winds, usually south or east. Slopes under 4% in fairly humid climates need to be paved. Slopes over 10% may erode in unpaved lots. A slight north or west slope usually can be graded to a 4% south or east slope. If possible, one should consider moving from present lot site to obtain desirable slope.

Complete land grading before construction begins. Slope away from buildings and feeding lines. The pens should have a 3% slope away from the feedbunks. Use surfaced roads and diversions of terraces as drainage ways to intercept water. Provide roof gutters and drains on sheds. Crown unsurfaced roads.

Minimum paving should be provided for heavy traffic areas, around waterers, and along feed lines. Additional paving may pay for itself if cattle would otherwise be in mud for extended periods. Generally, concrete has been the most satisfactory paving material. Concrete floors should be finished with wood float or broom to prevent slipping hazards for the cattle. Floors bearing cattle traffic should be 4 inches (10 cm) over tamped or undisturbed soil, or over gravel fill. Paving along bunks and around waters should be at least 8–10 ft wide (2.4–3 m) [20 ft (6.1 m) in muddy lots so that cattle may sleep on the apron at times of severe weather] with a 1/2-inch/ft slope (1 cm/23 cm), minimum. Aprons constructed with this slope will be nearly self-cleaning.

Feed Bunk Design for Beef Cattle

- Apron
  - 1/2 inch/ft (1 cm/23 cm), minimum, slope
  - 1 inch/ft (1 cm/12 cm) slope will be nearly self-cleaning
  - 5 ft (1.5 m) wide, minimum
  - 8 to 10 ft wide (2.4–3.0 m), with step, with paved space for passage of animals and tractor scraper
  - 20 ft wide (6.1 m) if area will be muddy or drifted with snow
- Bunk dimensions (excluding fence line bunks)
  - Widths: 48 inches (122 cm) of eating space if fed from both sides
    54 to 60 inches (137–152 cm) if bunk is divided by mechanical feeder
  - Height of bunk floor above apron: 4–6 inches (10–15 cm), where apron can be kept scraped; 12–16 inches (30–36 cm) if frozen mud, snow, etc., will accumulate
  - Throat height: up to 18 inches (46 cm) for calves, 22 inches (56 cm) for feeders and mature cows; increase to 30 inches (76 cm) only if hogs will run with the cattle

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Roof

Narrow roof, 5–6 ft (1.5–1.8 m) above apron for protection of bunk, and minimum shade. A roof over the bunk is needed only in high rainfall areas; one is

not required in drier parts of the United States, such as Colorado, Texas, and Western Nebraska. Wide roof sufficiently high to clear cleaning equipment provides shelter for bunk and cattle, plus summer shade. Too wide a roof may cause snow drifting and prevent as rapid thawing in northern regions.

Feeding space

Hand-feeding, as in twice/day, etc.

18–22 inches (48–55 cm), calves to 600 lb (273 kg)
22–26 inches (55–66 cm), 600 lb (273 kg) to market
26–30 inches (66–76 cm) for mature cows

When feeds are always available, as in self-feeding

4–6 inches (10–15 cm), for hay or silage
3–4 inches (7.6–10 cm), for grain or supplement
6 inches (15 cm), for grain and silage, mixed (bare minimum)
24 inches (61 cm), for new arrivals until they learn to eat from a bunk
Experienced cattle require less bunk space because they have learned to take their turns

Watering

40 head/watering space in drylot; 3–4 inches (7.6–10 cm) water space on pasture

Working Corrals

Holding pen, 20 square ft (1.9 square m)/head
Crowding pen, 15 square ft (1.6 square m)/head
150 square ft (14 square m), total minimum
Working alley for sorting, 10–12 ft (3–3.5 m) wide (3 m wide for working cattle on foot; 3.5 m wide for both on foot and with horses)
18–30 ft (5.5–9 m) long
Loading chute, 30 inches (76 cm) wide

Expansion

Plan for expansion. Allow for additional building and lot space, bunk length, and storage. Feed processing and handling facilities should be adapted to even larger capabilities than you had envisioned.

Shadows

In freezing climates, avoid continuous shadows in lots. Frozen manure and snow accumulate on the north side of buildings, silos, and bunks.

Buildings

Sheds open on one side should have the long, open side facing away from prevailing winter winds. The closed side should have doors or other provisions for summer ventilation. Floors should be at least 6 inches (15 cm) above outside

grade if floor is paved for feeding, at least 12 inches (30 cm) if unpaved, and should be sloped toward the large opening.

Storage, Processing

Plan for expansion. Locate to avoid shadows in lot, convenient to feeding area, and always away from cattle traffic patterns. Provide for all-weather access. Avoid interfering with summer breezes. Consider snow drifting patterns.

Feeding Lines

Orient up and down slope or provide drainage diversion. To avoid snow drifting and give up sun exposure on both sides, orient lines N–S, NE–SW, or NW–SE. On east or west slopes, orient bunks for equal exposure (N–S).

Manure

Provide temporary stockpile area unless removal can be done at the same time as cleaning. Avoid excess drainage water, but place at lower end of slope. Feedlots must be designed so that runoff from the pens is contained on the property. Regulations concerning runoff and water pollution will vary from state to state.

Appendix IV

Nutrient Requirements of Beef Cattle

Tilden Wayne Perry

TABLE AIV.1

Nutrient Requirements for Growing and Finishing Beef Cattle, Nutrient Concentration in Diet Dry Matter, Metric System

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
Medium-frame steer calves										
136	227	3.5	340	9.6	2.0	1.1	0.55	54	0.31	0.20
	454	3.8	431	11.4	2.1	1.3	0.68	58.5	0.45	0.24
	681	3.9	517	13.2	2.3	1.4	0.83	63	0.58	0.28
	908	4.0	599	14.8	2.4	1.5	0.97	67.5	0.72	0.32
	1135	4.0	672	16.7	2.7	1.7	1.12	73.5	0.87	0.37
	1362	3.6	726	19.9	2.8	2.1	1.41	85	1.13	0.47
181	227	4.4	395	8.9	2.0	1.1	0.55	54	0.27	0.18
	454	4.7	490	10.3	2.1	1.3	0.68	58.5	0.38	0.21
	681	4.9	563	11.5	2.3	1.4	0.83	63	0.47	0.25
	908	5.0	640	12.7	2.4	1.5	0.97	67.5	0.56	0.26
	1135	5.0	708	14.2	2.7	1.7	1.12	73.5	0.68	0.30
	1362	4.5	749	16.6	2.8	2.1	1.41	85	0.86	0.37
227	227	5.2	445	8.5	2.0	1.1	0.55	54	0.25	0.17
	454	5.6	526	9.5	2.1	1.3	0.68	58.5	0.32	0.20
	681	5.8	604	10.5	2.3	1.4	0.83	63	0.40	0.22
	908	6.0	676	11.4	2.4	1.5	0.97	67.5	0.47	0.24
	1135	5.9	740	12.5	2.7	1.7	1.12	73.5	0.56	0.27
	1362	5.4	767	14.4	2.8	2.1	1.41	85	0.69	0.32
272	227	6.0	490	8.2	2.0	1.1	0.55	54	0.23	0.18
	454	6.4	572	9.0	2.1	1.3	0.68	58.5	0.28	0.19
	681	6.7	645	9.8	2.3	1.4	0.83	63	0.35	0.21
	908	6.8	712	10.5	2.4	1.5	0.97	67.5	0.46	0.24
	1135	6.8	767	11.4	2.7	1.7	1.12	73.5	0.46	0.24
	1362	6.1	785	12.9	2.8	2.1	1.41	85	0.57	0.29
318	227	6.7	536	7.9	2.0	1.1	0.55	54	0.22	0.18
	454	7.2	613	8.6	2.1	1.3	0.68	58.5	0.27	0.18
	681	7.5	681	9.2	2.3	1.4	0.83	63	0.31	0.20
	908	7.6	749	9.8	2.4	1.5	0.97	67.5	0.34	0.21
	1135	7.6	794	10.5	2.7	1.7	1.12	73.5	0.40	0.22
	1362	6.9	804	11.7	2.8	2.1	1.41	85	0.49	0.26
363	227	7.4	576	7.7	2.0	1.1	0.55	54	0.22	0.17
	454	8.0	654	8.3	2.1	1.3	0.68	58.5	0.24	0.19
	681	8.3	722	8.8	2.3	1.4	0.83	63	0.28	0.19
	908	8.6	781	9.2	2.4	1.5	0.97	67.5	0.31	0.20
	1135	8.4	822	9.8	2.7	1.7	1.12	73.5	0.35	0.21
	1362	7.6	822	10.8	2.8	2.1	1.41	85	0.42	0.25
409	227	8.1	608	7.6	2.0	1.1	0.55	54	0.21	0.18
	454	8.7	690	8.0	2.1	1.3	0.68	58.5	0.23	0.18
	681	8.3	754	8.4	2.3	1.4	0.83	63	0.28	0.19
	908	9.2	808	8.8	2.4	1.5	0.97	67.5	0.28	0.20

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
	1135	9.2	849	9.3	2.7	1.7	1.12	73.5	0.31	0.20
	1362	8.3	840	10.1	2.8	2.1	1.41	85	0.37	0.23
454	227	8.8	658	7.5	2.0	1.1	0.55	54	0.21	0.18
	454	9.4	658	7.8	2.1	1.3	0.68	58.5	0.21	0.18
	681	9.8	790	8.1	2.3	1.4	0.83	63	0.24	0.18
	908	10.0	840	8.4	2.4	1.5	0.97	67.5	0.25	0.10
	1135	9.9	872	8.8	2.7	1.7	1.12	73.5	0.27	0.19
	1362	9.0	853	9.5	2.8	2.1	1.41	85	0.32	0.22
	Large-frame steer calves and compensating medium frame yearling steers									
136	227	3.7	350	9.5	1.9	1.1	0.51	52.5	0.30	0.19
	454	4.0	449	11.3	2.0	1.2	0.62	56	0.46	0.23
	681	4.1	540	12.9	2.2	1.3	0.73	59.5	0.58	0.27
	908	4.3	667	14.6	2.3	1.4	0.84	63.5	0.70	0.30
	1135	4.4	704	16.3	2.4	1.5	0.97	67.5	0.85	0.34
	1362	4.4	785	18.0	2.6	1.7	1.08	72	0.90	0.39
	1589	4.2	853	20.3	2.8	1.9	1.25	78.5	1.16	0.45
182	227	4.6	404	8.9	1.9	1.1	0.51	52.5	0.26	0.17
	454	4.9	499	10.2	2.0	1.2	0.62	56	0.37	0.20
	681	5.1	590	11.4	2.2	1.3	0.73	59.5	0.47	0.23
	908	5.3	667	12.7	2.3	1.4	0.84	63.5	0.57	0.26
	1135	5.4	744	13.9	2.4	1.5	0.97	67.5	0.65	0.30
	1362	5.4	822	15.2	2.6	1.7	1.08	72	0.76	0.33
	1589	5.2	880	16.9	2.8	1.9	1.25	78.5	0.90	0.36
227	227	5.4	454	8.5	1.9	1.1	0.51	52.5	0.24	0.17
	454	5.8	549	9.5	2.0	1.2	0.62	56	0.37	0.20
	681	6.1	636	10.4	2.2	1.3	0.73	59.5	0.39	0.21
	908	6.3	713	11.4	2.3	1.4	0.84	63.5	0.46	0.24
	1135	6.4	785	12.4	2.4	1.5	0.97	67.5	0.55	0.25
	1362	6.4	853	13.4	2.6	1.7	1.08	72	0.63	0.28
	1589	6.2	908	14.7	2.8	1.9	1.25	78.5	0.73	0.32
272	227	6.3	504	8.2	1.9	1.1	0.51	52.5	0.22	0.18
	454	6.6	595	9.0	2.0	1.2	0.62	56	0.29	0.18
	681	7.0	721	9.7	2.2	1.3	0.73	59.5	0.35	0.20
	908	7.2	754	10.5	2.3	1.4	0.84	63.5	0.40	0.22
	1135	7.3	854	11.3	2.4	1.5	0.97	67.5	0.47	0.23
	1362	7.3	885	12.1	2.6	1.7	1.08	72	0.52	0.26
	1589	7.1	931	13.2	2.8	1.9	1.25	78.5	0.61	0.28
318	227	7.0	549	7.9	1.9	1.1	0.51	52.5	0.21	0.17
	454	7.5	640	8.6	2.0	1.2	0.62	56	0.27	0.19
	681	7.8	722	9.2	2.2	1.3	0.73	59.5	0.31	0.19
	908	8.1	790	9.8	2.3	1.4	0.84	63.5	0.36	0.21

(*continues*)

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
	1135	8.2	853	10.5	2.4	1.5	0.97	67.5	0.40	0.22
	1362	8.2	912	11.1	2.6	1.7	1.08	72	0.45	0.23
	1589	8.0	953	12.0	2.8	1.9	1.25	78.5	0.52	0.26
364	227	7.8	595	7.7	1.9	1.1	0.51	52.5	0.21	0.18
	454	8.3	686	8.3	2.0	1.2	0.62	56	0.24	0.18
	681	8.6	762	8.8	2.2	1.3	0.73	59.5	0.28	0.19
	908	8.9	826	9.3	2.3	1.4	0.84	63.5	0.32	0.20
	1135	9.0	890	9.8	2.4	1.5	0.97	67.5	0.35	0.21
	1362	9.0	940	10.4	2.6	1.7	1.08	72	0.40	0.22
	1589	8.8	976	11.1	2.8	1.9	1.25	78.5	0.45	0.24
409	227	8.4	636	7.6	1.9	1.1	0.51	52.5	0.20	0.18
	454	9.0	726	8.0	2.0	1.2	0.62	56	0.23	0.18
	681	9.4	803	8.5	2.2	1.3	0.73	59.5	0.27	0.18
	908	9.7	863	8.9	2.3	1.4	0.84	63.5	0.29	0.20
	1135	9.9	922	9.3	2.4	1.5	0.97	67.5	0.31	0.20
	1362	9.9	967	9.8	2.6	1.7	1.08	72	0.36	0.21
	1589	9.6	994	10.4	2.8	1.9	1.25	78.5	0.40	0.23
454	227	9.2	676	7.5	1.9	1.1	0.51	52.5	0.20	0.17
	454	9.8	767	7.8	2.0	1.2	0.62	56	0.23	0.17
	681	10.2	840	8.2	2.2	1.3	0.73	59.5	0.25	0.16
	908	10.5	898	8.6	2.3	1.4	0.84	63.5	0.27	0.18
	1135	10.7	949	8.9	2.4	1.5	0.97	67.5	0.29	0.19
	1362	11.5	994	9.3	2.6	1.7	1.08	72	0.32	0.20
	1589	10.4	1016	9.8	2.8	1.9	1.25	78.5	0.35	0.21
500	227	9.9	717	7.4	1.9	1.1	0.51	52.5	0.19	0.18
	454	10.5	804	7.7	2.0	1.2	0.62	56	0.21	0.18
	681	11.0	876	8.0	2.2	1.3	0.73	59.5	0.23	0.18
	908	11.3	931	8.3	2.3	1.4	0.84	63.5	0.25	0.18
	1135	11.5	981	8.5	2.4	1.5	0.97	67.5	0.26	0.18
	1362	11.6	1021	8.9	2.6	1.7	1.08	72	0.29	0.19
	1589	11.1	1035	9.3	2.8	1.9	1.25	78.5	0.32	0.21
				Medium-frame bulls						
136	227	3.5	345	9.7	1.9	1.1	0.53	53.5	0.31	0.20
	454	3.7	435	11.6	2.1	1.2	0.66	57.5	0.48	0.24
	681	3.9	522	13.4	2.2	1.4	0.77	61.5	0.62	0.28
	908	4.0	608	15.2	2.4	1.5	0.90	65.5	0.75	0.33
	1135	4.0	690	17.0	2.5	1.6	1.03	70	0.92	0.37
	1362	4.0	763	19.3	2.8	1.8	1.19	76.5	1.09	0.43
182	227	4.4	395	9.0	1.9	1.1	0.53	53.5	0.28	0.18
	454	4.7	486	10.4	2.1	1.2	0.66	57.5	0.39	0.21
	681	4.9	572	11.8	2.2	1.4	0.77	61.5	0.49	0.25
	908	5.0	654	13.1	2.4	1.5	0.90	65.5	0.69	0.28

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
	1135	5.0	726	14.4	2.5	1.6	1.03	70	0.70	0.32
	1362	4.9	790	16.1	2.8	1.8	1.19	76.5	0.84	0.37
227	227	5.2	436	8.6	1.9	1.1	0.53	53.5	0.25	0.17
	454	5.5	531	9.7	2.1	1.2	0.66	57.5	0.35	0.20
	681	5.8	613	10.7	2.2	1.4	0.77	61.5	0.42	0.23
	908	5.9	690	11.7	2.4	1.5	0.90	65.5	0.49	0.25
	1135	6.0	763	12.8	2.5	1.6	1.03	70	0.59	0.27
	1362	5.8	822	14.1	2.8	1.8	1.19	76.5	0.69	0.31
272	227	6.0	490	8.3	1.9	1.1	0.53	53.5	0.24	0.19
	454	6.3	576	9.2	2.1	1.2	0.66	57.5	0.30	0.19
	681	6.6	654	10.0	2.2	1.4	0.77	61.5	0.36	0.21
	908	6.8	731	10.8	2.4	1.5	0.90	65.5	0.43	0.24
	1135	6.8	795	11.6	2.5	1.6	1.03	70	0.50	0.25
	1362	6.7	844	12.7	2.8	1.8	1.19	76.5	0.57	0.29
318	227	6.7	536	8.0	1.9	1.1	0.53	53.5	0.23	0.18
	454	7.1	622	8.8	2.1	1.2	0.66	57.5	0.28	0.20
	681	7.4	694	9.4	2.2	1.4	0.77	61.5	0.32	0.20
	908	7.6	767	10.1	2.4	1.5	0.90	65.5	0.38	0.22
	1135	7.6	826	10.8	2.5	1.6	1.03	70	0.42	0.24
	1362	7.5	872	11.7	2.8	1.8	1.19	76.5	0.49	0.25
364	227	7.4	577	7.8	1.9	1.1	0.53	53.5	0.22	0.19
	454	7.9	658	8.4	2.1	1.2	0.66	57.5	0.25	0.19
	681	8.2	731	9.0	2.2	1.4	0.77	61.5	0.29	0.20
	908	8.4	799	9.5	2.4	1.5	0.90	65.5	0.33	0.21
	1135	8.4	858	10.1	2.5	1.6	1.03	70	0.38	0.23
	1362	8.2	894	10.8	2.8	1.8	1.19	76.5	0.44	0.24
409	227	8.0	617	7.7	1.9	1.1	0.53	53.5	0.21	0.19
	454	8.6	699	8.2	2.1	1.2	0.66	57.5	0.25	0.18
	681	9.0	767	8.6	2.2	1.4	0.77	61.5	0.26	0.19
	908	9.2	831	9.1	2.4	1.5	0.90	65.5	0.31	0.21
	1135	9.2	885	9.6	2.5	1.6	1.03	70	0.34	0.22
	1362	9.0	917	10.2	2.8	1.8	1.19	76.5	0.39	0.23
454	227	8.7	658	7.5	1.9	1.1	0.53	53.5	0.21	0.18
	454	9.3	735	8.0	2.1	1.2	0.66	57.5	0.24	0.18
	681	9.7	803	8.4	2.2	1.4	0.77	61.5	0.26	0.19
	908	9.9	863	8.7	2.4	1.5	0.90	65.5	0.28	0.19
	1135	10.0	913	9.1	2.5	1.6	1.03	70	0.31	0.20
	1362	9.8	940	9.6	2.8	1.8	1.19	76.5	0.35	0.23
500	227	9.3	699	7.4	1.9	1.1	0.53	53.5	0.20	0.19
	454	10.0	772	7.8	2.1	1.2	0.66	57.5	0.22	0.19
	681	10.4	840	8.1	2.2	1.4	0.77	61.5	0.24	0.19
	908	10.6	894	8.4	2.4	1.5	0.90	65.5	0.26	0.19

(*continues*)

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
	1135	10.7	940	8.7	2.5	1.6	1.03	70	0.28	0.20
	1362	10.5	958	9.2	2.8	1.8	1.19	76.5	0.32	0.21
Large-frame bull calves and compensating large-frame yearling steers										
136	227	3.6	350	9.7	1.8	1.1	0.51	52.5	0.31	0.20
	454	3.8	444	11.7	2.0	1.2	0.61	56	0.47	0.24
	681	4.0	536	13.5	2.2	1.3	0.73	59.5	0.63	0.28
	908	4.1	627	15.1	2.3	1.4	0.81	62.5	0.76	0.32
	1135	4.2	708	17.0	2.4	1.5	0.92	66.5	0.91	0.36
	1362	4.2	790	18.8	2.6	1.7	1.03	70.5	1.08	0.43
	1589	4.1	867	20.9	2.7	1.8	1.16	75.5	1.24	0.48
	1816	3.7	926	24.7	3.1	2.1	1.45	86	1.53	0.59
182	227	4.5	404	9.0	1.8	1.1	0.51	52.5	0.27	0.16
	454	4.7	495	10.5	2.0	1.2	0.61	56	0.40	0.21
	681	5.0	586	11.9	2.2	1.3	0.73	59.5	0.51	0.24
	908	5.1	672	13.1	2.3	1.4	0.81	62.5	0.61	0.28
	1135	5.2	749	14.5	2.4	1.5	0.92	66.5	0.72	0.31
	1362	5.2	826	15.9	2.6	1.7	1.03	70.5	0.82	0.35
	1589	5.1	899	17.5	2.7	1.8	1.16	75.5	0.96	0.39
	1816	4.6	944	20.3	3.1	2.1	1.45	86	1.10	0.48
227	227	5.2	454	8.6	1.8	1.1	0.51	52.5	0.25	0.19
	454	5.6	545	9.8	2.0	1.2	0.61	56	0.36	0.21
	681	5.9	631	10.9	2.2	1.3	0.73	59.5	0.43	0.22
	908	6.0	717	11.8	2.3	1.4	0.81	62.5	0.52	0.25
	1135	6.1	790	12.9	2.4	1.5	0.92	66.5	0.59	0.26
	1362	6.2	863	14.0	2.6	1.7	1.03	70.5	0.68	0.31
	1589	6.1	931	15.3	2.7	1.8	1.16	75.5	0.77	0.35
	1816	5.4	967	17.5	3.1	2.1	1.45	86	0.97	0.40
272	227	6.0	499	8.3	1.8	1.1	0.51	52.5	0.23	0.18
	454	6.4	590	9.2	2.0	1.2	0.61	56	0.31	0.20
	681	6.7	672	10.1	2.2	1.3	0.73	59.5	0.37	0.21
	908	6.9	758	10.9	2.3	1.4	0.81	62.5	0.44	0.23
	1135	7.0	826	11.8	2.4	1.5	0.92	66.5	0.51	0.26
	1362	7.0	894	12.7	2.6	1.7	1.03	70.5	0.58	0.27
	1589	7.0	958	13.7	2.7	1.8	1.16	75.5	0.66	0.30
	1816	6.3	981	15.6	3.1	2.1	1.45	86	0.81	0.37
318	227	6.8	545	8.0	1.8	1.1	0.51	52.5	0.22	0.18
	454	7.2	636	8.8	2.0	1.2	0.61	56	0.29	0.19
	681	7.5	713	9.6	2.2	1.3	0.73	59.5	0.35	0.21
	908	7.7	794	10.2	2.3	1.4	0.81	62.5	0.39	0.22
	1135	7.9	863	11.0	2.4	1.5	0.92	66.5	0.44	0.24
	1362	8.0	926	11.7	2.6	1.7	1.03	70.5	0.50	0.25
	1589	7.8	980	12.5	2.7	1.8	1.16	75.5	0.56	0.28
	1816	7.0	999	14.1	3.1	2.1	1.45	86	0.70	0.33

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
364	227	7.5	590	7.9	1.8	1.1	0.51	52.5	0.21	0.19
	454	8.0	676	8.5	2.0	1.2	0.61	56	0.26	0.19
	681	8.3	754	9.1	2.2	1.3	0.73	59.5	0.31	0.20
	908	8.5	835	9.7	2.3	1.4	0.81	62.5	0.35	0.21
	1135	8.7	894	10.3	2.4	1.5	0.92	66.5	0.40	0.23
	1362	8.8	958	10.9	2.6	1.7	1.03	70.5	0.45	0.24
	1589	8.6	1007	11.6	2.7	1.8	1.16	75.5	0.50	0.26
	1816	7.7	1017	13.0	3.1	2.1	1.45	86	0.61	0.31
409	227	8.2	631	7.7	1.8	1.1	0.51	52.5	0.22	0.18
	454	8.7	717	8.3	2.0	1.2	0.61	56	0.25	0.18
	691	9.1	790	8.8	2.2	1.3	0.73	59.5	0.29	0.20
	908	9.4	872	9.2	2.3	1.4	0.81	62.5	0.32	0.20
	1135	9.5	926	9.8	2.4	1.5	0.92	66.5	0.36	0.21
	1362	9.6	985	10.3	2.6	1.7	1.03	70.5	0.40	0.23
	1589	9.4	1030	10.9	2.7	1.8	1.16	75.5	0.45	0.24
	1816	8.5	1030	12.1	3.1	2.1	1.45	86	0.53	0.28
454	227	8.9	672	7.6	1.8	1.1	0.51	52.5	0.21	0.18
	454	9.4	754	8.1	2.0	1.2	0.61	56	0.25	0.19
	691	9.9	831	8.5	2.2	1.3	0.73	59.5	0.27	0.19
	908	10.1	903	8.9	2.3	1.4	0.81	62.5	0.30	0.20
	1135	10.3	958	9.3	2.4	1.5	0.92	66.5	0.33	0.20
	1362	10.4	1012	9.7	2.6	1.7	1.03	70.5	0.30	0.21
	1589	10.2	1053	10.3	2.7	1.8	1.16	75.5	0.40	0.24
	1816	9.2	1044	11.3	3.1	2.1	1.45	86	0.48	0.27
500	227	9.5	713	7.5	1.8	1.1	0.51	52.5	0.21	0.19
	454	10.1	794	7.9	2.0	1.2	0.61	56	0.23	0.19
	691	10.6	867	8.3	2.2	1.3	0.73	59.5	0.26	0.19
	908	10.8	940	8.6	2.3	1.4	0.81	62.5	0.28	0.19
	1135	11.0	981	9.0	2.4	1.5	0.92	66.5	0.30	0.20
	1362	11.1	1039	9.3	2.6	1.7	1.03	70.5	0.32	0.21
	1589	11.0	1076	9.8	2.7	1.8	1.16	75.5	0.36	0.22
	1816	9.9	1057	10.7	3.1	2.1	1.45	86	0.43	0.25
				Medium-frame heifers						
136	227	3.4	331	9.0	2.0	1.2	0.62	56	0.29	0.21
	454	3.6	413	11.4	2.2	1.4	0.79	62	0.44	0.32
	691	3.7	490	13.1	2.5	1.6	0.97	68.5	0.59	0.27
	908	3.6	554	15.1	2.8	1.8	1.21	77	0.74	0.33
182	227	4.2	381	8.9	2.0	1.2	0.62	56	0.26	0.19
	454	4.5	458	10.2	2.2	1.4	0.79	62	0.36	0.20
	691	4.6	531	11.4	2.5	1.6	0.97	68.5	0.45	0.24
	908	4.5	586	12.9	2.8	1.8	1.21	77	0.57	0.29

(*continues*)

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
227	227	5.0	427	8.5	2.0	1.2	0.62	56	0.24	0.18
	454	5.4	504	9.4	2.2	1.4	0.79	62	0.30	0.21
	691	5.5	568	10.3	2.5	1.6	0.97	68.5	0.38	0.22
	908	5.4	613	11.4	2.8	1.8	1.21	77	0.45	0.24
272	227	5.7	472	8.1	2.0	1.2	0.62	56	0.23	0.18
	454	6.1	540	8.8	2.2	1.4	0.79	62	0.28	0.20
	691	6.3	600	9.5	2.5	1.6	0.97	68.5	0.32	0.21
	908	6.1	640	10.4	2.8	1.8	1.21	77	0.38	0.23
318	227	6.4	513	7.9	2.0	1.2	0.62	56	0.22	0.19
	454	6.9	581	8.4	2.2	1.4	0.79	62	0.25	0.19
	691	7.0	631	9.0	2.5	1.6	0.97	68.5	0.28	0.20
	908	6.9	663	9.6	2.8	1.8	1.21	77	0.32	0.22
364	227	7.1	554	7.7	2.0	1.2	0.62	56	0.21	0.18
	454	7.6	617	8.1	2.2	1.4	0.79	62	0.22	0.18
	691	7.8	663	8.5	2.5	1.6	0.97	68.5	0.24	0.19
	908	7.6	685	9.0	2.8	1.8	1.21	77	0.28	0.20
409	227	7.8	595	7.5	2.0	1.2	0.62	56	0.21	0.18
	454	8.3	654	7.5	2.2	1.4	0.79	62	0.22	0.18
	691	8.5	695	8.1	2.5	1.6	0.97	68.5	0.22	0.19
	908	8.3	708	8.5	2.8	1.8	1.21	77	0.25	0.19
454	227	8.4	631	7.4	2.0	1.2	0.62	56	0.20	0.19
	454	9.0	685	7.6	2.2	1.4	0.79	62	0.20	0.18
	691	9.2	722	7.8	2.5	1.6	0.97	68.5	0.21	0.18
	908	9.0	731	8.1	2.8	1.8	1.21	77	0.22	0.19
	Large-frame heifer calves and compensating medium-frame yearling heifers									
136	227	3.5	345	9.5	2.0	1.1	0.55	54	0.31	0.20
	454	3.8	431	11.3	2.2	1.3	0.70	59	0.45	0.24
	691	4.0	513	13.0	2.3	1.4	0.86	64	0.58	0.25
	908	4.0	590	14.6	2.5	1.6	1.01	69.5	0.69	0.30
	1135	4.0	658	16.7	2.8	1.8	1.21	77	0.86	0.35
182	227	4.4	395	8.9	2.0	1.1	0.55	54	0.27	0.18
	454	4.7	481	10.1	2.2	1.3	0.70	59	0.30	0.21
	691	5.0	558	11.3	2.3	1.4	0.86	64	0.45	0.22
	908	5.0	626	12.6	2.5	1.6	1.01	69.5	0.54	0.26
	1135	4.8	685	14.1	2.8	1.8	1.21	77	0.65	0.31
227	227	5.2	445	8.4	2.0	1.1	0.55	54	0.23	0.17
	454	5.6	527	9.4	2.2	1.3	0.70	59	0.30	0.20
	691	5.9	600	10.3	2.3	1.4	0.86	64	0.38	0.20
	908	6.0	663	11.2	2.5	1.6	1.01	69.5	0.44	0.24
	1135	5.8	713	12.4	2.8	1.8	1.21	77	0.53	0.26
272	227	6.0	490	8.1	2.0	1.1	0.55	54	0.22	0.18
	454	6.4	568	8.9	2.2	1.3	0.70	59	0.28	0.19
	691	6.7	640	9.6	2.3	1.4	0.86	64	0.33	0.19

TABLE AIV.1 (*Continued*)

Body weight (kg)	Daily gain (g)	Dry matter intake (kg)	Protein intake (g)	Protein (%)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDN (%)	Ca (%)	P (%)
	908	6.8	700	10.3	2.5	1.6	1.01	69.5	0.38	0.22
	1135	6.6	740	11.2	2.8	1.8	1.21	77	0.44	0.24
318	227	6.7	536	7.9	2.0	1.1	0.55	54	0.21	0.18
	454	7.2	608	8.5	2.2	1.3	0.70	59	0.25	0.18
	691	7.5	676	9.0	2.3	1.4	0.86	64	0.29	0.19
	908	7.6	731	9.6	2.5	1.6	1.01	69.5	0.33	0.20
	1135	7.4	762	10.3	2.8	1.8	1.21	77	0.38	0.22
364	227	7.4	577	7.7	2.0	1.1	0.55	54	0.21	0.18
	454	8.0	649	8.2	2.2	1.3	0.70	59	0.24	0.18
	691	8.3	713	8.6	2.3	1.4	0.86	64	0.25	0.18
	908	8.4	758	9.0	2.5	1.6	1.01	69.5	0.28	0.19
	1135	8.2	790	9.6	2.8	1.8	1.21	77	0.33	0.21
409	227	8.1	617	7.5	2.0	1.1	0.55	54	0.20	0.18
	454	8.7	690	7.9	2.2	1.3	0.70	59	0.22	0.18
	691	9.1	744	8.2	2.3	1.4	0.86	64	0.23	0.18
	908	9.2	790	8.6	2.5	1.6	1.01	69.5	0.26	0.18
	1135	8.9	808	9.0	2.8	1.8	1.21	77	0.29	0.20
454	227	8.7	658	7.4	2.0	1.1	0.55	54	0.19	0.18
	454	9.4	726	7.7	2.2	1.3	0.70	59	0.21	0.18
	691	9.9	776	8.0	2.3	1.4	0.86	64	0.21	0.18
	908	10.0	817	8.2	2.5	1.6	1.01	69.5	0.23	0.18
	1135	9.6	840	8.6	2.8	1.8	1.21	77	0.25	0.18
500	227	9.4	699	7.3	2.0	1.1	0.55	54	0.19	0.18
	454	10.1	763	7.5	2.2	1.3	0.70	59	0.20	0.18
	691	10.5	808	7.7	2.3	1.4	0.86	64	0.20	0.18
	908	10.7	844	7.9	2.5	1.6	1.01	69.5	0.21	0.18
	1135	10.5	853	8.2	2.8	1.8	1.21	77	0.22	0.18

Note. Vitamin A requirement is 2200 IU/kg of diet. The data presented in this table are a modification of Table 10, "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Science, Washington, DC, 1984.

Table AIV.2

Nutrient Requirements of Breeding Cattle (Metric System)

Weight (kg)	Gain (g/day)	Intake (DM/day)	In diet dry matter: TDN (%)	ME (Mcal/kg dry matter)	NE_m (Mcal/kg dry matter)	NE_g (Mcal/kg dry matter)	Total protein (gm/day)	Ca (g/%)	P (g/%)	Vitamin A IU/day (×1000)
Pregnant yearling heifers—Last third of pregnancy										
318	409	7.0	55.4	2.0	1.1	NA	590	0.27	0.20	19
	636	7.2	60.3	2.2	1.3	0.75	636	0.33	0.21	20
	863	7.2	67.0	2.4	1.5	0.95	681	0.33	0.21	20
340	409	7.3	55.1	2.0	1.1	NA	590	0.27	0.19	20
	636	7.5	59.5	2.2	1.3	0.73	681	0.32	0.21	21
	863	7.5	66.5	2.4	1.5	0.92	726	0.37	0.23	21
363	409	7.6	54.8	2.0	1.1	NA	636	0.28	0.20	21
	636	7.9	56.9	2.2	1.3	0.73	681	0.33	0.21	22
	863	8.0	66.1	2.4	1.5	0.92	726	0.35	0.21	22
386	409	8.0	54.5	2.0	1.1	NA	636	0.26	0.20	22
	636	8.3	59.3	2.2	1.3	0.70	726	0.30	0.21	23
	863	8.3	65.7	2.4	1.5	0.90	772	0.34	0.22	23
409	409	8.3	54.3	2.0	1.1	NA	681	0.26	0.20	23
	636	8.6	59.1	2.2	1.3	0.70	726	0.30	0.21	24
	863	8.7	65.4	2.4	1.5	0.90	772	0.32	0.21	24
432	409	8.6	54.1	2.0	1.1	NA	681	0.27	0.20	24
	636	9.0	58.9	2.1	1.1	0.70	772	0.29	0.21	25
	863	9.1	65.1	2.4	1.5	0.88	817	0.32	0.21	25
Dry pregnant mature cows—Middle third of pregnancy										
364	0	7.0	48.8	1.8	0.9	NA	499	0.17	0.17	19
409	0	7.6	48.8	1.8	0.9	NA	545	0.18	0.18	21
454	0	8.2	48.8	1.8	0.9	NA	590	0.18	0.18	23
500	0	8.9	48.8	1.8	0.9	NA	636	0.19	0.19	26
545	0	9.4	48.8	1.8	0.9	NA	636	0.19	0.19	28
591	0	10.0	48.8	1.8	0.9	NA	681	0.20	0.20	28
636	0	10.6	48.8	1.8	0.9	NA	726	0.21	0.20	30
Dry pregnant cows—Last third of pregnancy										
364	409	7.6	54.5	2.0	1.1	NA	636	0.26	0.20	21
409	409	8.3	54.0	2.0	1.1	NA	681	0.27	0.21	23
454	409	8.9	53.6	1.9	1.1	NA	726	0.26	0.20	25
500	409	9.5	53.2	1.9	1.1	NA	726	0.26	0.21	26
545	409	10.1	52.9	1.9	1.1	NA	772	0.26	0.21	28
591	409	10.7	52.7	1.9	1.1	NA	817	0.26	0.21	30
636	409	11.3	52.5	1.8	1.1	NA	863	0.26	0.21	32
Two-year-old heifers nursing calves—First 3–4 months postpartum, 4.5 kg milk/day										
318	227	7.2	65.1	2.4	1.5	0.88	817	0.36	0.24	28
341	227	7.6	64.4	2.3	1.4	0.88	817	0.34	0.24	30
364	227	8.0	63.8	2.3	1.4	0.84	863	0.34	0.24	31
386	227	8.4	63.2	2.3	1.4	0.84	863	0.33	0.23	33
409	227	8.7	62.7	2.3	1.4	0.81	908	0.32	0.23	34

Table AIV.2 (*Continued*)

Weight (kg)	Gain (g/day)	Intake (DM/day)	In diet dry matter: TDN (%)	ME (Mcal/kg dry matter)	NE_m (Mcal/kg dry matter)	NE_g (Mcal/kg dry matter)	Total protein (gm/day)	Ca (g/%)	P (g/%)	Vitamin A IU/day (×1000)
432	227	9.1	62.3	2.2	1.4	0.81	908	0.31	0.23	35
454	227	9.5	61.9	2.2	1.4	0.79	953	0.31	0.23	37
Cows nursing calves—Average nursing ability, First 3–4 months postpartum, 4.5 kg milk/day										
364	0	7.9	58.2	2.1	1.3	NA	817	0.30	0.23	31
409	0	8.5	57.3	2.1	1.2	NA	863	0.28	0.22	33
454	0	9.2	56.9	2.0	1.2	NA	908	0.28	0.22	36
500	0	9.8	56.0	2.0	1.2	NA	908	0.27	0.22	38
545	0	10.4	55.5	2.0	1.2	NA	953	0.27	0.22	41
591	0	11.0	55.1	2.0	1.1	NA	999	0.27	0.22	43
636	0	11.6	54.7	2.0	1.1	NA	1044	0.27	0.22	46
Cows nursing calves—Superior milking ability, First 3–4 months postpartum, 9.1 kg milk/day										
364	0	7.1	77.3	2.8	1.9	NA	1000	0.48	0.31	28
409	0	8.5	69.8	2.5	1.6	NA	1089	0.41	0.28	33
454	0	9.4	67.0	2.4	1.5	NA	1135	0.39	0.27	37
500	0	10.1	65.2	2.4	1.5	NA	1180	0.38	0.27	40
545	0	10.8	63.7	2.3	1.4	NA	1226	0.36	0.26	42
591	0	11.5	62.6	2.3	1.4	NA	1271	0.36	0.26	45
636	0	12.3	61.7	2.2	1.4	NA	1316	0.35	0.26	47
Bulls, maintenance and slow growth rate (regain body condition)										
591	454	11.5	55.8	2.0	1.2	0.62	862	0.22	0.19	45
	681	11.9	59.7	2.2	1.3	0.73	908	0.24	0.19	46
	908	11.9	64.0	2.3	1.4	0.86	1000	0.26	0.20	46
636	454	12.2	55.8	2.0	1.2	0.62	908	0.21	0.19	48
	681	12.5	59.7	2.2	1.3	0.73	953	0.23	0.19	49
	908	12.6	64.0	2.3	1.4	0.86	1000	0.25	0.20	49
682	0	11.5	48.4	1.7	0.9	NA	772	0.20	0.20	45
	454	12.9	55.8	2.0	1.2	0.62	953	0.21	0.19	50
	681	13.2	59.7	2.2	1.3	0.73	1000	0.22	0.19	51
727	0	12.0	48.4	1.7	0.9	NA	817	0.19	0.20	47
	454	13.5	55.8	2.0	1.2	0.62	1000	0.22	0.19	53
	681	13.8	59.7	2.2	1.3	0.73	1044	0.22	0.20	54
772	0	12.6	48.4	1.7	0.9	NA	863	0.21	0.21	49
	227	13.5	52.0	1.9	1.0	0.48	953	0.20	0.19	52
818	0	13.1	48.4	1.7	0.9	NA	908	0.21	0.21	51
	227	14.0	52.0	1.9	1.0	0.48	1000	0.20	0.20	55
864	0	13.7	48.4	1.7	0.9	NA	908	0.21	0.21	53
	227	14.6	52.0	1.9	1.0	0.48	1000	0.20	0.20	57
909	0	14.2	48.4	1.7	0.9	NA	953	0.21	0.21	55
954	0	14.8	48.4	1.7	0.9	NA	1000	0.22	0.22	58
1000	0	15.3	48.4	1.7	0.9	NA	1044	0.22	0.22	60

Note. Approximately 400 gm of weight gain per day of females during the last one-third of pregnancy is accounted for by the products of conception. Daily 2.15 Mcal of NE_m and 454 g protein are provided for this requirement for a calf with a birth weight of 36 kg. In determining energy and protein requirements for milk production, 0.75 Mcal of NE_m and 35 g of protein is included for each kg of milk produced.

TABLE AIV.3

Nutrient Requirements for Beef Cattle Breeding Herd (Daily Nutrients per Animal)[a]

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)	Vitamin A (thousands) (IU)
		Pregnant yearling heifers—Last 3–4 months of pregnancy						
716	0.9	14.5	100	1.28	7.7	15	15	19
	1.3	18.7	100	1.65	9.9	18	18	23
	1.8	20.7	85–100	1.87	12.3	22	20	26
772	0.9	15.2	100	1.34	8.1	15	15	19
	1.3	19.6	100	1.72	10.3	19	19	25
	1.8	22.0	85–100	1.94	12.9	22	21	28
827	0.9	15.9	100	1.39	8.4	15	15	20
	1.3	20.5	100	1.78	10.8	19	19	26
	1.8	24.2	85–100	2.11	13.5	22	22	31
882	0.9	16.5	100	1.43	8.7	16	16	21
	1.3	21.4	100	1.85	11.3	19	19	27
	1.8	25.6	85–100	2.22	14.0	22	22	33
937	0.9	17.2	100	1.52	9.0	16	16	22
	1.3	22.3	100	1.94	11.7	19	19	28
	1.8	26.7	85–100	2.31	14.6	22	22	34
		Dry pregnant cows—Middle third of pregnancy						
772		12.2	100	0.70	6.6	10	10	15
882		13.4	100	0.79	7.3	11	11	17
992		14.8	100	0.86	7.9	12	12	19
1102		15.9	100	0.93	8.6	13	13	20
1213		17.0	100	0.99	9.2	14	14	22
1323		18.3	100	1.08	9.8	15	15	23
1433		19.4	100	1.14	10.4	16	16	25
		Dry pregnant mature cows—Last third of pregnancy						
772	0.9	13.9	100	0.42	8.0	12	12	19
882	0.9	15.4	100	0.97	8.7	14	14	21
992	0.9	16.5	100	1.06	9.4	15	15	23
1102	0.9	17.9	100	1.12	10.0	15	15	24
1213	0.9	19.0	100	1.19	10.7	16	16	26
1323	0.9	20.3	100	1.26	11.2	17	17	27
1433	0.9	22.4	100	1.32	11.9	18	18	29
		Cows nursing calves—Average milking ability, first 3–4 months postpartum						
772		18.1	100	1.65	9.7	24	24	19
882		19.4	100	1.78	10.4	25	25	21
992		20.5	100	1.89	11.0	26	26	23
1102		21.6	100	1.98	11.7	27	27	24
1213		23.1	100	2.14	12.3	28	28	26
1323		24.2	100	2.22	13.0	28	28	27
1433		25.1	100	2.31	13.7	29	29	29

TABLE AIV.3 (*Continued*)

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)	Vitamin A (thousands) (IU)
Cows nursing calves—Superior milking ability, first 3–4 months postpartum								
772		22.4	100	2.44	12.8	45	40	32
882		23.8	100	2.58	13.5	45	41	34
992		24.9	100	2.71	14.1	45	42	36
1102		26.0	100	2.84	14.8	46	43	38
1213		27.3	100	2.97	15.4	46	44	41
1323		28.4	100	3.10	16.1	46	44	43
1433		29.5	100	3.22	16.8	47	45	45
Bulls, growth and maintenance (moderate activity)								
661	2.2	19.4	70–75	1.98	12.3	27	23	34
882	2.0	24.2	70–75	2.27	15.4	23	23	43
1102	1.5	26.9	80–85	2.35	16.5	22	22	48
1323	1.1	26.4	80–85	2.25	16.1	22	22	48
1543	0.7	28.4	90–100	2.38	17.0	23	23	50
1764	0	23.1	100	1.96	12.8	19	19	41
1984	0	25.1	100	2.18	13.9	21	21	44
2205	0	27.3	100	2.31	15.2	22	22	48

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Sciences, Washington, D.C., 1984, Table 10. With permission.

TABLE AIV.4

Nutrient Requirements for Growing–Finishing Steer Calves and Yearlings (Nutrient Concentration in Diet Dry Matter)[a,b]

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
220	0	4.6	100	8.7	55	0.18	0.18
	1.1	6.4	70–80	12.4	62	0.48	0.38
	1.5	6.0	50–60	14.8	70	0.70	0.48
	2.0	6.2	25–30	16.4	77	0.86	0.57
	2.4	6.0	<15	18.2	86	1.04	0.70
331	0	6.2	100	8.7	55	0.18	0.18
	1.1	8.8	70–80	11.0	62	0.35	0.32
	1.5	8.6	50–60	12.6	70	0.46	0.36

(*continues*)

TABLE AIV.4 (*Continued*)

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
	2.0	8.4	25–30	14.1	77	0.61	0.45
	2.4	8.2	<15	15.6	86	0.76	0.54
441	0	7.7	100	8.5	55	0.18	0.18
	1.1	12.8	80–90	9.9	58	0.24	0.22
	1.5	12.6	70–80	10.8	64	0.32	0.28
	2.0	10.8	35–45	12.3	75	0.47	0.37
	2.4	10.1	<15	13.6	86	0.59	0.43
551	0	9.7	100	8.5	55	0.18	0.18
	1.5	12.8	55–65	10.7	70	0.31	0.28
	2.0	13.7	45–50	11.1	72	0.35	0.31
	2.4	13.2	20–25	12.1	77	0.43	0.35
	2.9	13.2	<15	12.7	86	0.50	0.38
661	0	10.4	100	8.6	55	0.18	0.18
	2.0	17.9	55–65	10.0	70	0.27	0.23
	2.4	16.8	20–25	10.8	77	0.33	0.29
	2.9	15.6	<15	11.7	83	0.41	0.32
	3.1	16.1	<15	11.9	86	0.42	0.34
772	0	11.7	100	8.5	55	0.18	0.18
	2.0	17.6	45–55	10.0	72	0.25	0.22
	2.4	17.6	20–25	10.4	80	0.29	0.25
	2.9	17.6	<15	10.8	83	0.32	0.28
	3.1	18.1	<15	10.9	86	0.34	0.29
882	0	13.0	100	8.5	55	0.18	0.18
	2.2	20.7	45–55	9.4	72	0.22	0.21
	2.6	18.7	20–25	10.2	80	0.27	0.25
	2.9	19.0	<15	10.4	86	0.29	0.26
	3.1	19.8	<15	10.5	86	0.29	0.26
992	0	14.1	100	8.5	55	0.18	0.18
	2.2	22.7	45–55	9.3	72	0.19	0.19
	2.6	22.5	20–25	9.5	80	0.23	0.22
	2.9	20.5	<15	10.4	86	0.26	0.25
	3.1	21.6	<15	10.0	86	0.26	0.23
1102	0	15.4	100	8.5	55	0.18	0.18
	2.0	23.1	45–55	9.1	72	0.18	0.18
	2.4	22.9	20–25	9.2	80	0.19	0.19
	2.6	21.2	<15	10.0	86	0.22	0.22
	2.9	22.0	<15	9.7	86	0.22	0.22

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Sciences, Washington, D.C., 1984, Table 10. With permission.

[b]The concentration of vitamin A in all diets for growing and finishing steer calves and yearlings is 1000 IU/lb dry diet.

TABLE AIV.5

Nutrient Requirements for Growing–Finishing Heifer Calves and Yearlings (Nutrient Concentration in Diet Dry Matter)[a,b]

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
220	0	4.6	100	8.7	55	0.18	0.18
	1.1	6.6	70–80	12.4	61	0.47	0.37
	1.5	6.4	50–60	14.4	69	0.66	0.48
	2.0	6.6	25–30	15.9	77	0.80	0.57
	2.4	6.6	<15	17.8	86	0.97	0.63
331	0	6.2	100	8.7	55	0.18	0.18
	1.1	9.0	70–80	11.0	61	0.34	0.29
	1.5	8.8	50–60	12.4	69	0.45	0.35
	2.0	8.8	25–30	13.5	77	0.57	0.42
	2.4	8.8	<15	15.0	86	0.70	0.50
441	0	7.7	100	8.5	55	0.18	0.18
	0.7	11.9	100	9.1	55	0.18	0.18
	1.1	13.2	80–90	9.6	58	0.23	0.22
	1.5	13.2	70–80	10.2	64	0.30	0.27
	2.0	11.7	35–45	11.7	75	0.41	0.32
	2.4	11.0	<15	12.8	86	0.50	0.38
551	0	9.0	100	8.5	55	0.18	0.18
	0.7	14.1	100	8.9	55	0.18	0.18
	1.1	14.3	80–90	9.5	58	0.20	0.20
	1.5	12.8	55–65	10.5	72	0.29	0.26
	2.0	13.0	35–45	11.1	77	0.36	0.29
	2.4	14.3	20–25	11.4	80	0.38	0.31
	2.6	13.9	<15	11.9	86	0.43	0.33
661	0	10.4	100	8.6	55	0.18	0.18
	0.7	16.3	100	8.5	55	0.18	0.18
	1.1	16.3	80–90	9.2	61	0.19	0.19
	1.5	14.6	55–65	10.1	72	0.24	0.23
	2.0	15.0	35–45	10.4	77	0.28	0.25
	2.4	16.5	20–25	10.4	80	0.31	0.27
	2.6	15.9	<15	10.9	86	0.33	0.28
772	0	11.7	100	8.5	55	0.18	0.18
	0.7	18.1	100	8.5	55	0.18	0.18
	1.1	18.3	80–90	8.7	61	0.18	0.18
	1.5	17.4	55–65	9.2	69	0.19	0.19
	2.0	17.9	35–45	9.5	75	0.21	0.21
	2.4	18.3	20–25	9.9	80	0.24	0.23
	2.6	17.9	<15	10.0	86	0.26	0.25
882	0	13.0	100	8.5	55	0.18	0.18
	0.7	20.0	100	8.5	55	0.18	0.18

(continues)

TABLE AIV.5 (*Continued*)

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
	1.1	18.7	70–80	8.8	64	0.18	0.18
	1.5	19.2	55–65	9.0	66	0.18	0.18
	2.0	18.5	20–25	9.4	77	0.20	0.20
	2.4	18.3	<15	9.7	86	0.23	0.22
992	0	14.1	100	8.5	55	0.18	0.18
	0.4	19.2	100	8.5	55	0.18	0.18
	1.1	20.5	70–80	8.6	64	0.18	0.18
	1.8	20.1	35–45	9.0	75	0.18	0.18
	2.2	18.7	<15	9.5	86	0.22	0.22

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Science, Washington, D.C., 1984, Table 10. With permission.

[b]The concentration of vitamin A in all diets for growing and finishing heifers is 2000 IU/lb dry diet.

TABLE AIV.6

Nutrient Requirements for Beef Cattle Breeding Herd (Nutrient Concentration in Diet Dry Matter)[a,b]

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
		Pregnant yearling heifers—Last third of pregnancy					
716	0.9	14.5	100	8.8	52	0.23	0.23
	1.3	18.7	100	8.8	52	0.21	0.21
	1.8	20.7	85–100	9.0	58	0.23	0.21
772	0.9	15.2	100	8.8	52	0.22	0.22
	1.3	19.6	100	8.8	52	0.21	0.21
	1.8	22.0	85–100	8.8	58	0.22	0.21
827	0.9	15.9	100	8.7	52	0.21	0.21
	1.3	20.5	100	8.7	52	0.20	0.20
	1.8	24.2	85–100	8.7	55	0.20	0.20
882	0.9	16.5	100	8.7	52	0.21	0.21
	1.3	21.4	100	8.7	52	0.20	0.20
	1.8	25.6	85–100	8.7	55	0.19	0.19
937	0.9	17.2	100	8.8	52	0.20	0.20
	1.3	22.3	100	8.7	52	0.19	0.19
	1.8	26.7	85–100	8.7	55	0.18	0.18
		Dry pregnant mature cows—Middle third of pregnancy					
772		12.2	100	5.9	52	0.18	0.18
882		13.4	100	5.9	52	0.18	0.18

TABLE AIV.6 (*Continued*)

Weight (lb)	Daily gain (lb)	Minimum dry matter consumption (lb)	Roughage (%)	Total protein (lb)	TDN (lb)	Ca (g)	P (g)
992		14.8	100	5.9	52	0.18	0.18
1102		15.9	100	5.9	52	0.18	0.18
1213		17.0	100	5.9	52	0.18	0.18
1323		18.3	100	5.9	52	0.18	0.18
1433		19.4	100	5.9	52	0.18	0.18
Dry pregnant mature cows—Last third of pregnancy							
772	0.9	13.9	100	5.9	52	0.18	0.18
882	0.9	15.4	100	5.9	52	0.18	0.18
992	0.9	17.9	100	5.9	52	0.18	0.18
1102	0.9	17.9	100	5.9	52	0.18	0.18
1213	0.9	19.0	100	5.9	52	0.18	0.18
1323	0.9	20.3	100	5.9	52	0.18	0.18
1433	0.9	22.4	100	5.9	52	0.18	0.18
Cows nursing calves—Average milking ability, first 3–4 months postpartum							
772		18.1	100	9.2	52	0.29	0.29
882		19.4	100	9.2	52	0.28	0.28
992		20.5	100	9.2	52	0.28	0.28
1102		21.6	100	9.2	52	0.28	0.28
1213		23.1	100	9.2	52	0.27	0.27
1323		24.2	100	9.2	52	0.25	0.25
1433		25.1	100	9.2	52	0.25	0.25
Cows nursing calves—Superior milking ability, first 3–4 months postpartum							
772		22.4	100	10.9	55	0.44	0.39
882		23.8	100	10.9	55	0.42	0.38
992		24.9	100	10.9	55	0.40	0.37
1102		26.0	100	10.9	55	0.39	0.36
1213		27.3	100	10.9	55	0.37	0.35
1323		28.4	100	10.9	55	0.36	0.34
1433		29.5	100	10.9	55	0.35	0.33
Bulls, growth and maintenance (moderate activity)							
661	2.2	19.4	70–75	10.2	64	0.31	0.26
882	2.0	24.2	70–75	9.4	64	0.21	0.21
1102	1.5	26.9	80–85	8.8	61	0.18	0.18
1323	1.1	26.4	80–85	8.8	61	0.18	0.18
1543	0.7	28.4	90–100	8.5	55	0.18	0.18
1764	0.0	23.1	100	8.5	55	0.18	0.18
1984	0.0	25.1	100	8.5	55	0.18	0.18
2205	0.0	27.3	100	8.5	55	0.18	0.18

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Sciences, Washington, D.C., 1984, Table 11. With permission.

[b]The concentration of vitamin A in all diets for pregnant heifers and cows is 1300 IU/lb dry diet; for lactating cows and breeding bulls, 1800 IU/lb.

TABLE AIV.7

Net Energy Requirements of Growing and Finishing Beef Cattle (Megacalories per Animal per Day)[a]

	Body weight (lb)								
Daily gain (lb):	220	330	440	550	660	770	880	990	1100
NE_g require:	(2.43)[b]	(3.30)	(4.10)	(4.84)	(5.55)	(6.24)	(6.89)	(7.52)	(8.14)
Steers									
0.2	0.17	0.23	0.28	0.34	0.39	0.43	0.48	0.52	0.56
0.4	0.34	0.46	0.57	0.68	0.78	0.88	0.97	1.06	1.14
0.7	0.52	0.70	0.87	1.03	1.18	1.33	1.47	1.61	1.74
0.9	0.70	0.95	1.18	1.40	1.60	1.80	1.99	2.17	2.34
1.1	0.89	1.20	1.49	1.77	2.02	2.27	2.51	2.74	2.97
1.3	1.08	1.46	1.81	2.15	2.46	2.76	3.05	3.33	3.60
1.5	1.27	1.73	2.14	2.53	2.90	3.26	3.60	3.93	4.25
1.8	1.47	2.00	2.47	2.93	3.36	3.77	4.17	4.55	4.92
2.0	1.68	2.27	2.82	3.33	3.82	4.29	4.74	5.18	5.60
2.2	1.88	2.55	3.16	3.75	4.29	4.82	5.33	5.82	6.29
2.4	2.10	2.84	3.52	4.17	4.78	5.36	5.93	6.47	7.01
2.6	2.31	3.13	3.88	4.60	5.27	5.92	6.54	7.14	7.73
2.9	2.53	3.43	4.26	5.04	5.77	6.48	7.16	7.83	8.47
3.1	2.76	3.74	4.63	5.49	6.29	7.06	7.80	8.52	9.22
3.3	2.99	4.05	5.02	5.95	6.81	7.65	8.46	9.23	9.98
Heifers									
0.2	0.18	0.25	0.30	0.36	0.41	0.46	0.51	0.56	0.61
0.4	0.37	0.50	0.62	0.74	0.84	0.95	1.05	1.14	1.24
0.7	0.57	0.77	0.95	1.13	1.29	1.45	1.61	1.75	1.90
0.9	0.77	1.05	0.30	1.54	1.76	1.98	2.18	2.39	2.58
1.1	0.99	1.34	1.66	1.96	2.25	2.52	2.79	3.05	3.30
1.3	1.21	1.64	2.03	2.40	2.75	3.09	3.41	3.73	4.03
1.5	1.44	1.95	2.42	2.86	3.27	3.68	4.06	4.44	4.80
1.8	1.67	2.28	2.81	3.33	3.82	4.28	4.73	5.17	5.59
2.0	1.92	2.60	3.23	3.81	4.37	4.91	5.43	5.93	6.41
2.2	2.17	2.94	3.65	4.32	4.95	5.56	6.14	6.71	7.26
2.4	2.43	3.30	4.09	4.84	5.55	6.23	6.88	7.52	8.13
2.6	2.70	3.66	4.55	5.37	6.16	6.91	7.64	8.35	9.03
2.9	2.98	4.04	5.01	5.92	6.79	7.63	8.42	9.21	9.96
3.1	3.26	4.42	5.49	6.49	7.44	8.36	9.23	10.09	10.91
3.3	3.56	4.82	5.98	7.07	8.11	9.11	10.06	11.00	11.90

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Sciences, Washington, D.C., 1984, Table 7. With permission.

[b]Numbers in parentheses are NE_m required to achieve body weight given.

TABLE AIV.8

Mineral and Vitamin Requirements of Beef Cattle (in Percentage of Diet Dry Matter or Amount per Pound of Dry Diet)[a]

Nutrient	Growing and finishing steers and heifers	Dry pregnant cows	Breeding bulls and lactating cows	Possible toxic levels (mg/lb diet)
Vitamin A activity (IU)	1000	1272	1770	
Vitamin D (IU)	125	125	125	
Vitamin E (IU)	7–27	—	7–27	
Minerals				
Sodium (%)	0.06	0.06	0.06	
Calcium (%)	0.18–1.04	0.18	0.18–0.44	
Phosphorus (%)	0.18–0.70	—[b]	0.18–0.39	
Magnesium (%)	0.04–0.10	—[b]	0.18	
Potassium (%)	0.6–0.8	—[b]	—[b]	
Sulfur (%)	0.1	—[b]	—[b]	
Iodine (μg)	0.5	0.2–2.0	—[b]	50
Iron (mg)	4	—[b]	—[b]	1000
Copper (mg)	2	—[b]	—[b]	50
Cobalt (mg)	0.02–0.04	0.02–0.04	0.02–0.04	4–6
Manganese (mg)	0.4–4.5	9	—[b]	68
Zinc (mg)	9.1–13.6	—[b]	—[b]	410
Selenium (mg)	0.04	0.02–0.04	0.04–0.04	2

[a]Modified from "Nutrient Requirements of Beef Cattle," 6th rev. ed., National Academy of Sciences, Washington, D.C., 1984, Table 3. With permission.

[b]Unknown.

[c]See Table 1.4 for more details.

Appendix V

Typical Composition of Feedstuffs for Cattle

Tilden Wayne Perry

Typical Composition of Feedstuffs for Cattle
(All Values except Dry Matter Are Shown on a Dry Matter Basis)

	Fiber							Minerals					Energy			
Feedstuffs	DM (%)	CP (%)	EE (%)	CF (%)	ADF (%)	NDF (%)	Ash (%)	Ca (%)	P (%)	K (%)	S (%)	Zn (ppm)	TDN (%)	DE (Mcal/ lb)	NE_m (Mcal/ lb)	ND_g (Mcal/ lb)
Alfalfa cubes	91	18	2.0	29	34	45	11	1.3	0.23	1.9	0.35	18	57	1.14	0.56	0.25
Alfalfa dehydrated 17% protein	92	19	3.3	26	32	45	10	1.4	0.25	2.7	0.29	17	62	1.24	0.62	0.33
Alfalfa fresh	26	21	2.2	27	32	44	8	1.6	0.32	2.3	0.34	21	57	1.14	0.56	0.25
Alfalfa hay early bloom	90	18	2.2	29	35	47	8	1.4	0.25	2.3	0.30	18	57	1.14	0.56	0.25
Alfalfa hay mid-bloom	89	17	2.0	30	38	50	10	1.4	0.23	1.8	0.30	17	56	1.12	0.55	0.23
Alfalfa hay full bloom	88	16	1.8	34	41	56	8	1.3	0.20	1.7	0.29	17	53	1.06	0.52	0.18
Alfalfa hay mature	90	14	1.7	38	45	59	8	1.3	0.19	1.4	0.25	17	50	1.00	0.49	0.12
Alfalfa silage wilted	36	18	2.8	30	35	46	10	1.5	0.28	2.4	0.30	17	56	1.12	0.55	0.23
Alfalfa seed screenings	90	28	7.0	16	—	—	7	0.03	0.67	—	—	—	76	1.52	0.80	0.52
Alfalfa stems	89	11	1.3	44	51	68	6	0.9	0.18	2.5	—	—	47	0.94	0.46	0.07
Almond hulls	90	3	3.0	11	28	30	10	0.4	0.06	0.5	0.11	—	67	1.34	0.68	0.40
Apple pomace wet	20	6	5.9	17	—	—	4	0.1	0.10	0.5	0.02	—	73	1.46	0.76	0.48
Apple pomace dried	89	4	3.4	15	—	—	2	0.1	0.12	0.5	0.02	—	69	1.38	0.70	0.43
Bagasse sugar cane	91	1	0.7	49	59	86	3	0.9	0.29	0.5	0.10	—	36	0.72	0.37	0.0
Bakery product dried	91	11	13.0	1	—	—	3	0.1	0.35	0.6	0.02	15	89	1.78	0.98	0.67
Barley silage	32	10	4.0	34	—	—	10	0.3	0.30	1.6	0.17	—	50	1.00	0.49	0.12
Barley silage mature	40	9	4.0	34	—	—	10	0.2	0.30	1.5	0.15	—	67	1.34	0.68	0.40
Barley straw	88	4	1.9	42	57	82	7	0.3	0.05	2.0	0.15	7	44	0.88	0.43	0.01
Barley grain	89	12	2.0	6	7	19	3	0.1	0.40	0.5	0.16	20	82	1.64	0.88	0.59
Barley grain light weight	88	13	2.3	9	—	—	4	0.0	—	—	—	—	79	1.58	0.84	0.55
Barley grain screenings	89	13	2.6	9	—	—	4	0.0	0.40	0.1	0.15	—	81	1.62	0.87	0.58
Beans navy cull	90	24	1.4	5	—	—	6	0.1	0.50	1.4	0.26	—	84	1.68	0.91	0.61

Beet pulp wet	11	10	2.0	20	34	59	5	0.9	0.10	0.2	0.22	1	68	1.36	0.69	0.41
Beet pulp dried	91	9	0.8	21	34	59	5	0.8	0.08	0.2	0.22	1	72	1.44	0.74	0.47
Beet pulp wet with molasses	24	12	0.5	16	27	47	9	0.6	0.10	1.8	0.36	11	76	1.52	0.80	0.52
Beet pulp dry with molasses	92	12	0.5	16	27	47	9	0.6	0.10	1.8	0.36	11	76	1.52	0.80	0.52
Beet tops sugar	20	13	1.4	9	—	—	25	0.7	0.24	4.8	0.45	20	58	1.16	0.57	0.26
Beet top silage	25	10	2.0	10	—	—	38	1.2	0.22	5.7	—	—	52	1.04	0.51	0.16
Bermudagrass coastal dehydrated	90	16	3.8	27	24	40	7	0.3	0.25	—	0.22	—	62	1.24	0.62	0.33
Bermudagrass hay coastal	91	9	2.0	30	33	75	5	0.4	0.18	1.5	0.14	—	49	0.98	0.48	0.11
Bermudagrass hay	91	9	1.9	30	35	77	8	0.5	0.21	1.7	0.21	—	49	0.98	0.48	0.11
Birdsfoot trefoil fresh	22	21	4.7	21	—	—	7	1.8	0.25	2.3	0.25	—	70	1.40	0.72	0.44
Birdsfoot trefoil hay	89	16	2.2	30	34	44	8	1.8	0.22	1.8	0.25	—	57	1.14	0.56	0.25
Bluegrass Kentucky fresh early bloom	36	14	3.9	27	—	—	7	0.5	0.39	2.3	0.12	25	72	1.44	0.74	0.47
Blue grass straw	93	6	1.1	40	50	78	6	0.2	0.10	—	—	—	45	0.90	0.44	0.03
Bluestem fresh mature	61	6	2.5	34	—	—	4	0.3	0.14	1.0	0.05	28	46	0.92	0.45	0.05
Bone meal steamed	95	13	11.6	1	—	—	79	30.7	12.86	0.2	0.25	130	16	0.32	0.34	0.0
Brewers grains wet	24	26	6.5	16	21	34	5	0.3	0.57	0.1	0.36	100	81	1.62	0.87	0.58
Brewers dried grains	92	28	7.5	15	19	32	4	0.3	0.57	0.1	0.36	100	81	1.62	0.87	0.58
Brewers yeast dried	94	48	1.0	3	—	—	7	0.1	1.56	1.8	0.41	41	79	1.58	0.84	0.55
Brome grass fresh immature	32	15	4.1	28	33	54	10	0.4	0.39	2.7	0.20	—	64	1.28	0.64	0.36
Brome grass hay	89	10	2.5	32	39	69	9	0.5	0.23	2.5	0.16	—	52	1.04	0.51	0.16
Buckwheat grain	88	12	2.8	11	—	—	2	0.1	0.36	0.5	0.16	10	79	1.58	0.84	0.55
Buttermilk dried	94	34	5.6	0	0	0	10	1.5	1.03	1.1	0.09	44	88	1.76	0.97	0.65
Cactus	32	6	2.1	27	23	29	16	2.9	—	—	—	—	65	1.30	0.65	0.37
Calcium carbonate	99	0	0.0	0	0	0	99	39.0	0.04	—	0.09	—	0	0.0	0.0	0.0
Cattle manure dried	92	15	2.6	34	37	57	10	1.3	1.00	0.5	—	240	41	0.82	0.41	0.0

(continues)

Typical Composition of Feedstuffs for Cattle (*Continued*)

	Fiber							Minerals					Energy			
Feedstuffs	DM (%)	CP (%)	EE (%)	CF (%)	ADF (%)	NDF (%)	Ash (%)	Ca (%)	P (%)	K (%)	S (%)	Zn (ppm)	TDN (%)	DE (Mcal/ lb)	NE_m (Mcal/ lb)	ND_g (Mcal/ lb)
Cheatgrass fresh immature	21	16	2.7	23	—	—	10	0.6	0.28	—	—	—	68	1.36	0.69	0.41
Citrus pulp dried	90	7	4.1	13	22	23	6	1.8	0.12	1.0	0.20	14	77	1.54	0.81	0.53
Clover ladino fresh	19	25	4.8	14	—	—	11	1.3	0.42	2.2	0.20	39	69	1.38	0.70	0.43
Clover ladino hay	90	21	2.0	24	—	—	9	1.7	0.32	2.4	0.22	17	61	1.22	0.61	0.31
Clover red fresh	24	18	4.0	24	33	44	9	1.7	0.26	2.0	0.17	23	64	1.28	0.64	0.36
Clover red hay	88	15	2.9	30	41	56	8	1.4	0.22	1.9	0.17	17	59	1.18	0.58	0.28
Coffee grounds	88	13	22.3	41	68	80	1	0.1	0.08	—	—	—	13	0.26	0.20	0.0
Corn whole plant pellets	91	9	2.4	21	—	—	6	0.5	0.24	1.0	0.14	—	63	1.26	0.63	0.34
Corn fodder	80	9	2.4	27	29	48	7	0.3	0.18	1.0	0.14	—	65	1.30	0.65	0.37
Corn stover mature	80	5	1.3	35	41	71	7	0.5	0.09	1.6	0.17	—	59	1.18	0.58	0.28
Corn silage milk stage	26	8	2.8	26	31	—	6	0.3	0.24	1.6	0.12	25	67	1.34	0.68	0.40
Corn silage mature well eared	36	8	2.7	23	—	—	7	0.3	0.20	1.0	0.11	24	69	1.38	0.70	0.43
Corn grain dent yellow	88	10	4.0	3	3	10	2	0.0	0.30	0.4	0.14	14	90	1.80	0.99	0.68
Corn grain high lysine	92	12	4.4	4	—	—	2	0.0	0.24	0.3	0.11	—	84	1.68	0.91	0.61
Corn and cob meal	87	9	3.7	9	10	25	2	0.1	0.26	0.5	0.21	10	82	1.64	0.88	0.59
Corn cobs	90	3	0.5	36	43	88	2	0.1	0.04	0.8	0.47	5	48	0.96	0.47	0.09
Corn gluten feed	90	27	2.9	8	—	—	7	0.5	0.86	0.6	0.24	100	82	1.64	0.88	0.59
Corn gluten meal	91	43	2.5	5	—	—	4	0.2	0.51	0.0	0.85	45	84	1.68	0.91	0.61
Corn cannery waste	29	8	3.0	28	36	59	5	0.1	0.29	1.0	0.13	25	68	1.36	0.69	0.41
Cotton gin trash	90	7	1.7	37	—	—	9	0.3	0.16	—	—	—	44	0.88	0.43	0.01
Cottonseed hulls	90	4	1.5	48	67	86	3	0.1	0.07	1.0	0.09	22	44	0.88	0.43	0.01
Cottonseed meal screw press 41% protein	93	45	6.0	13	22	30	7	0.2	1.18	1.4	0.33	63	78	1.56	0.82	0.54

Cottonseed meal solvent 41% protein	92	46	2.2	13	22	30	7	0.2	1.16	1.4	0.36	66	75	1.50	0.78	0.50
Crambe meal solvent	92	34	1.1	25	—	—	6	1.2	1.30	—	—	—	70	1.40	0.72	0.44
Cranberry pulp dried	88	7	15.7	26	47	54	2	—	—	—	—	—	49	0.98	0.48	0.11
Curaco phosphate	99	0	0.0	0	0	0	95	34.0	15.00	—	—	—	0	0.0	0.0	0.0
Defluorinated phosphate	99	0	0.0	0	0	0	95	32.6	18.07	1.0	—	100	0	0.0	0.0	0.0
Diammonium phosphate	98	115	0.0	0	0	0	35	0.5	20.41	—	—	—	0	0.0	0.0	0.0
Dicalcium phosphate	96	0	0.0	0	0	0	94	21.0	18.65	0.1	—	70	0	0.0	0.0	0.0
Distiller's grains corn	92	30	8.2	14	16	39	2	0.1	0.43	0.2	0.46	35	84	1.68	0.91	0.61
Distiller's grains corn with solubles	92	29	9.8	10	—	—	5	0.2	0.85	0.7	0.32	90	87	1.74	0.95	0.64
Distiller's dried solubles	92	30	9.5	4	—	—	8	0.4	1.48	1.9	0.40	91	88	1.76	0.97	0.65
Fat animal–poultry	99	0	99.0	0	0	0	0	0.0	0.0	0.0	0.0	0	198	3.96	2.43	1.84
Feather meal hydrolyzed	94	91	3.3	2	20	20	4	0.2	0.78	0.3	2.00	53	68	1.36	0.69	0.41
Fescue Kentucky 31 fresh	29	15	5.5	25	—	—	10	0.4	0.35	2.6	—	22	66	1.32	0.67	0.38
Fescue Kentucky 31 hay early bloom	88	18	6.6	25	—	—	9	0.5	0.37	—	—	—	64	1.28	0.64	0.36
Fescue Kentucky 31 hay mature	89	14	5.2	28	38	65	7	0.4	0.25	—	—	—	60	1.20	0.59	0.30
Fescue straw (red)	94	4	1.1	41	—	—	6	0.0	0.06	—	—	—	43	0.86	0.43	0.0
Garbage municipal cooked	23	16	23.3	8	50	59	11	1.6	0.45	—	—	—	75	1.50	0.78	0.50
Grain screenings	90	15	5.5	14	—	—	9	0.5	0.43	—	—	17	63	1.26	0.63	0.34
Grain dust	91	11	3.2	15	—	—	12	0.3	0.18	—	—	42	72	1.44	0.74	0.47
Grape pomace stemless	91	12	7.5	32	50	53	9	0.6	0.06	0.6	—	24	30	0.60	0.37	0.0
Grass silage	26	12	4.6	34	38	66	9	0.8	0.22	2.0	—	29	61	1.22	0.61	0.31
Hominy feed	90	12	7.7	6	12	56	3	0.1	0.58	0.7	0.06	3	95	1.90	1.06	0.73
Hop leaves	37	15	3.6	15	—	—	35	2.8	0.64	—	—	—	49	0.98	0.48	0.11
Hop vine silage	30	15	3.1	21	—	—	20	3.3	0.37	1.8	0.22	44	53	1.06	0.52	0.18
Hops spent	89	22	4.0	28	—	—	7	1.6	0.60	—	—	—	39	0.78	0.40	0.0

(continues)

Typical Composition of Feedstuffs for Cattle (*Continued*)

				Fiber						Minerals					Energy	
Feedstuffs	DM (%)	CP (%)	EE (%)	CF (%)	ADF (%)	NDF (%)	Ash (%)	Ca (%)	P (%)	K (%)	S (%)	Zn (ppm)	TDN (%)	DE (Mcal/ lb)	NE_m (Mcal/ lb)	ND_g (Mcal/ lb)
Lespedeza fresh early bloom	25	16	2.0	32	—	—	10	1.4	0.21	1.1	0.21	—	67	1.34	0.68	0.40
Limestone ground	98	0	0.0	0	0	0	96	33.8	0.02	—	—	—	0	0.0	0.0	0.0
Linseed meal solvent	91	40	1.9	10	17	25	6	0.4	0.91	1.5	0.40	35	76	1.52	0.80	0.52
Meadow hay	92	8	2.5	33	—	—	9	0.6	0.17	—	—	—	46	0.92	0.45	0.05
Milo grain	89	11	3.2	3	8	17	2	0.0	0.32	0.4	0.18	15	80	1.60	0.85	0.56
Molasses beet	77	9	0.2	0	0	0	11	0.2	0.04	6.1	0.60	18	79	1.58	0.84	0.55
Molasses cane	76	5	0.0	0	0	0	10	1.0	0.10	4.0	0.46	30	81	1.62	0.87	0.58
Molasses cane dried	94	11	0.6	3	0	0	14	1.2	0.15	4.0	0.46	30	81	1.62	0.87	0.58
Molasses citrus	65	11	0.3	0	0	0	9	2.0	0.25	0.2	0.23	137	77	1.54	0.81	0.53
Molasses wood	59	1	0.5	1	—	—	7	1.9	0.04	0.1	0.05	—	77	1.54	0.81	0.53
Monoammonium phosphate	98	74	0.0	0	0	0	24	0.5	24.77	—	0.71	81	0	0.0	0.0	0.0
Mono-dicalcium phosphate	97	0	0.0	0	0	0	94	16.7	21.10	0.1	—	70	0	0.0	0.0	0.0
Oat hay	87	9	2.1	30	38	63	9	0.2	0.22	1.0	0.30	39	59	1.18	0.58	0.28
Oat silage	34	11	3.8	30	—	—	10	0.4	0.25	3.4	0.32	35	58	1.16	0.57	0.26
Oat straw	90	4	2.3	41	46	70	8	0.3	0.10	2.2	0.22	6	52	1.04	0.51	0.16
Oats grain	89	14	4.0	12	17	31	4	0.1	0.38	0.5	0.19	18	74	1.48	0.77	0.49
Oat groats	91	18	6.6	3	—	—	2	0.1	0.47	0.4	0.22	—	93	1.86	1.03	0.71
Oat meal feeding	90	17	6.0	4	—	—	3	0.1	0.51	0.5	0.29	—	94	1.88	1.05	0.72
Oat mill by-product	90	7	2.5	23	—	—	6	0.1	0.24	0.6	—	—	33	0.66	0.37	0.0
Oat hulls	93	5	1.5	32	44	81	7	0.2	0.15	0.6	0.15	—	37	0.74	0.39	0.0
Orange pulp dried	89	9	1.8	9	—	—	4	0.7	0.11	—	—	—	87	1.74	0.95	0.64

Orchardgrass fresh immature	24	18	5.0	24	27	45	11	0.4	0.40	2.7	0.22	20	65	1.30	0.65	0.37
Orchardgrass hay	88	11	3.3	34	40	70	7	0.3	0.28	2.8	0.26	18	59	1.18	0.58	0.28
Pea vine hay	89	10	1.8	32	—	—	7	1.2	0.21	1.8	0.17	15	60	1.20	0.59	0.30
Pea vine silage	24	13	3.3	31	—	—	8	1.3	0.24	—	0.29	—	57	1.14	0.56	0.25
Pea straw	89	7	1.3	45	—	—	7	—	0.11	1.1	0.20	—	56	1.12	0.55	0.23
Peas cull	89	25	1.5	8	—	—	5	0.2	0.43	1.1	0.26	30	79	1.58	0.84	0.55
Peanut hulls	92	7	1.3	65	65	74	5	0.2	0.07	0.9	—	—	22	0.44	0.35	0.0
Peanut meal solvent	92	52	1.3	14	—	—	5	0.2	0.71	1.2	0.30	22	77	1.54	0.81	0.53
Pineapple green chop	17	9	2.6	23	35	64	8	—	—	—	—	—	45	0.90	0.44	0.03
Pineapple bran	89	5	1.2	20	28	59	3	0.3	0.10	—	—	—	72	1.44	0.74	0.47
Pineapple presscake	21	5	1.1	20	36	69	3	0.2	0.12	—	—	—	72	1.44	0.74	0.47
Potatoes cull	21	10	0.4	2	—	—	5	0.0	0.24	2.2	0.09	—	80	1.60	0.85	0.56
Potato waste wet	14	7	1.5	9	—	—	3	0.2	0.26	1.3	0.11	12	82	1.64	0.88	0.59
Potato waste dried	89	8	0.5	7	—	—	5	0.1	0.13	1.2	—	—	85	1.70	0.92	0.62
Potato waste wet with lime	17	5	0.3	10	—	—	9	4.2	0.18	—	—	—	80	1.60	0.85	0.56
Poultry litter dried	86	30	2.8	20	—	—	16	2.7	1.85	1.8	—	235	64	1.28	0.64	0.36
Poultry manure dried	89	30	2.1	15	16	33	28	8.6	2.30	1.7	—	400	53	1.06	0.52	0.18
Prairie hay	91	7	2.0	35	—	—	8	0.4	0.13	1.1	—	34	50	1.00	0.49	0.12
Rapeseed meal solvent	91	41	2.2	14	—	—	8	0.7	1.10	1.4	0.28	66	70	1.40	0.72	0.44
Rice straw ammoniated	87	9	1.3	39	53	68	6	0.3	0.10	1.0	0.11	—	45	0.90	0.44	0.03
Rice polishings	90	14	13.1	4	—	—	8	0.1	1.37	1.1	0.19	28	89	1.78	0.98	0.67
Rice bran	91	13	15.2	13	20	26	13	0.1	1.68	1.9	0.20	33	66	1.32	0.67	0.38
Rice hulls	92	3	0.9	44	70	80	20	0.1	0.08	0.3	0.09	—	13	0.26	0.33	0.0
Rice mill feed	91	7	5.4	33	—	—	—	0.4	0.62	—	—	—	42	0.84	0.42	0.0
Rye straw	89	4	1.5	44	55	71	6	0.3	0.10	1.0	0.11	—	44	0.88	0.43	0.01
Rye grain	89	13	1.7	2	—	—	2	0.1	0.38	0.5	0.17	34	81	1.62	0.87	0.58
Safflower meal solvent	91	22	1.0	33	41	59	6	0.3	0.80	0.8	0.20	44	55	1.10	0.54	0.21

(*continues*)

Typical Composition of Feedstuffs for Cattle *(Continued)*

Feedstuffs	DM (%)	CP (%)	EE (%)	Fiber: CF (%)	Fiber: ADF (%)	Fiber: NDF (%)	Ash (%)	Minerals: Ca (%)	Minerals: P (%)	Minerals: K (%)	Minerals: S (%)	Minerals: Zn (ppm)	Energy: TDN (%)	Energy: DE (Mcal/ lb)	Energy: NE_m (Mcal/ lb)	Energy: ND_g (Mcal/ lb)
Safflower meal dehulled solvent	91	49	0.6	9	—	—	7	0.3	1.83	1.3	0.22	36	76	1.52	0.80	0.52
Sagebrush fresh	50	13	9.2	25	—	—	10	1.0	0.25	—	0.22	—	50	1.00	0.49	0.12
Sodium tripolyphosphate	96	0	0.0	0	0	0	96	0.0	25.98	—	—	—	0	0.0	0.0	0.0
Sorghum stover	85	5	2.1	33	—	—	10	0.4	0.11	1.5	—	—	57	1.14	0.56	0.25
Sorghum silage	31	8	2.8	24	21	39	7	0.4	0.11	1.5	0.11	32	57	1.14	0.56	0.25
Soybean hay	89	15	2.2	37	—	—	8	1.3	0.32	1.0	0.24	24	52	1.04	0.51	0.16
Soybean straw	88	5	1.4	44	54	70	6	1.6	0.06	0.6	0.26	—	42	0.84	0.42	0.0
Soybeans whole	91	42	19.2	6	—	—	5	0.3	0.63	1.8	0.24	60	92	1.84	1.02	0.70
Soybean meal solvent 44% protein	89	52	1.3	6	10	12	7	0.3	0.73	2.1	0.48	48	82	1.64	0.88	0.59
Soybean meal solvent 49% protein	90	56	1.2	3	—	—	6	0.3	0.71	2.2	0.48	61	84	1.68	0.91	0.61
Soybran flakes (hulls)	91	12	2.8	39	44	60	4	0.6	0.17	1.0	0.09	24	65	1.30	0.65	0.37
Sudangrass fresh immature	18	17	3.9	31	—	—	9	0.5	0.31	2.0	0.04	—	70	1.40	0.72	0.44
Sudangrass hay	89	10	1.8	31	43	68	10	0.4	0.30	2.1	0.06	—	59	1.18	0.58	0.28
Sudangrass silage	23	10	3.1	34	—	—	10	0.4	0.25	3.5	0.05	—	57	1.14	0.56	0.25
Sunflower meal solvent	93	50	3.1	12	—	—	8	0.6	0.54	1.1	—	—	65	1.30	0.65	0.37
Sunflower meal with hulls	90	32	1.4	27	—	—	7	0.4	1.04	0.9	0.33	—	57	1.14	0.56	0.25

Sunflower hulls	90	5	2.2	25	63	—	3	0.0	0.11	—	—	—	40	0.80	0.41	0.0
Timothy fresh prebloom	26	11	3.8	32	—	—	7	0.4	0.28	2.1	0.21	24	61	1.22	0.61	0.31
Timothy hay early bloom	88	8	2.6	33	43	68	6	0.5	0.25	0.9	0.21	—	59	1.18	0.58	0.28
Timothy hay full bloom	88	7	2.5	34	45	70	5	0.4	0.20	1.6	0.13	17	57	1.14	0.56	0.25
Tomato pomace dried	92	23	10.6	26	50	55	6	0.4	0.59	3.6	—	—	67	1.34	0.68	0.40
Triticale silage	38	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Triticale	90	16	4.6	4	—	—	2	0.1	0.34	0.4	0.17	—	86	1.72	0.94	0.63
Turnip tops (purple)	17	16	2.6	10	—	—	14	3.2	0.34	3.0	0.27	—	69	1.38	0.70	0.43
Turnip roots	9	12	1.5	11	—	—	8	0.8	0.40	3.4	0.43	40	86	1.72	0.94	0.63
Urea 45% N	98	287	0.0	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0.0
Wheat fresh (pasture)	21	28	4.0	18	—	—	14	0.4	0.40	3.5	—	—	69	1.38	0.70	0.43
Wheat silage	28	10	3.2	28	—	—	8	0.3	0.27	1.2	0.23	—	63	1.26	0.63	0.34
Wheat straw	88	3	1.5	42	56	85	7	0.2	0.08	1.2	0.14	7	44	0.88	0.43	0.01
Wheat grain hard	89	14	2.0	3	—	—	2	0.1	0.45	0.5	0.17	16	89	1.78	0.98	0.67
Wheat grain soft	89	12	2.0	3	—	—	2	0.1	0.35	0.4	0.17	16	89	1.78	0.98	0.67
Wheat bran	89	18	4.8	11	12	44	7	0.2	1.32	1.4	0.25	105	70	1.40	0.72	0.44
Wheat middlings	88	18	3.9	3	—	—	3	0.1	0.57	0.6	0.22	70	90	1.80	0.99	0.68
Wheat mill run	90	17	4.7	9	—	—	6	0.1	1.15	1.4	0.28	—	75	1.50	0.78	0.50
Wheat shorts	89	20	5.4	7	—	—	5	0.1	0.99	1.1	0.19	118	80	1.60	0.85	0.56
Wheatgrass crested fresh early bloom	37	11	1.6	30	—	—	7	0.3	0.30	—	—	—	58	1.16	0.57	0.26
Wheatgrass crested fresh full bloom	50	10	1.6	33	—	—	7	0.4	0.28	—	—	—	55	1.10	0.54	0.21
Wheatgrass crested hay	92	10	2.4	33	—	—	7	0.3	0.15	—	—	32	54	1.08	0.53	0.20
Whey dried	94	16	0.9	0	0	0	10	1.0	0.81	1.6	1.10	3	84	1.68	0.91	0.61

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ANIMAL FEEDING AND NUTRITION

A Series of Monographs and Treatises

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